1995

Causality tracing user interface design and development for a software management flight simulator

Hernandez, Luis.

Monterey, California. Naval Postgraduate School

NAVAL POSTGRADUATE SCHOOL
MONTEREY, CALIFORNIA

THESIS

CAUSALITY TRACING USER INTERFACE DESIGN AND DEVELOPMENT FOR A SOFTWARE MANAGEMENT FLIGHT SIMULATOR

by

Luis Hernández

December 1995

Thesis Advisor: Tarek Abdel-Hamid

Approved for public release; distribution is unlimited.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE December 1995	3. REPORT TYPE AND DATES COVERED Master's Thesis

4. TITLE AND SUBTITLE
CAUSALITY TRACING USER INTERFACE DESIGN AND DEVELOPMENT FOR A SOFTWARE MANAGEMENT FLIGHT SIMULATOR

5. FUNDING NUMBERS

6. AUTHOR(S)
Hernández, Luis

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(maximum 200 words)*

Interactive simulations are a highly suitable tool for training managers in their increasingly complex roles in software project management. This research effort designs and implements an interactive user-friendly interface for the system dynamics software development and project management model using a flight simulator as a metaphor. Methods and techniques for good user interface development are considered and implemented using the Ventana Simulation (Vensim) application development, modeling, and analysis environment. The resulting interface facilitates the user experimentation with management policy strategies and decision making, as well as the investigation of scenarios to determine what the circumstances were that caused the project's expected behavior to vary. The analysis capabilities of the interface enables the user to trace cause-and-effect relationships that are often invisible and not considered when making management decisions. The interface's causal tracing functionality significantly enhances the value of the underlying model as a learning tool by facilitating the development of an integrated, improved vision of the world that managers are responsible to control.

14. SUBJECT TERMS Simulations, Software Project Management, System Dynamics, User Interfaces,

15. NUMBER OF PAGES
188

16. PRICE CODE

17. SECURITY CLASSIFI-CATION OF REPORT Unclassified	18. SECURITY CLASSIFI-CATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFI CATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18 298-102

Approved for public release; distribution is unlimited.

CAUSALITY TRACING USER INTERFACE DESIGN AND DEVELOPMENT FOR A SOFTWARE MANAGEMENT FLIGHT SIMULATOR

Luis Hernández
Major, United States Army
B.S., University of Puerto Rico, 1983

Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN INFORMATION TECHNOLOGY MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
December 1995

Author: [redacted]
Luis Hernández

Approved by: [redacted]
Tarek Abdel-Hamid, Thesis Advisor

[redacted]
Balasubramaniam Ramesh, Associate Advisor

[redacted]
Reuben T. Harris, Chairman, Systems Management

ABSTRACT

Interactive simulations are a highly suitable tool for training managers in their increasingly complex roles in software project management. This research effort designs and implements an interactive user-friendly interface for the system dynamics software development and project management model using a flight simulator as a metaphor. Methods and techniques for good user interface development are considered and implemented using the Ventana Simulation (Vensim) application development, modeling, and analysis environment. The resulting interface facilitates the user experimentation with management policy strategies and decision making, as well as the investigation of scenarios to determine what the circumstances were that caused the project's expected behavior to vary. The analysis capabilities of the interface enables the user to trace cause-and-effect relationships that are often invisible and not considered when making management decisions. The interface's causal tracing functionality significantly enhances the value of the underlying model as a learning tool by facilitating the development of an integrated, improved vision of the world that managers are responsible to control.

TABLE OF CONTENTS

I. INTRODUCTION

A. BACKGROUND

Modern businesses depend on quick delivery and use of complex information in today's highly competitive electronic economic environment. Technological advances in computer hardware are making computers more powerful and affordable. The tendency is for more companies to migrate their business activities to the electronic commerce environment. This migration has created a strong dependence on software to run business critical applications. Presently, businesses are automating key processes in order to gain a competitive edge, market shares, and merge into the national and global markets.

Key business factors, such as time to market, quality levels, manufacturing costs, and product innovations provide the impetus and motivation for companies to demand new and better software products for their critical applications. Companies require flexible and comprehensive software environments for information systems that can handle their needs as fast as their market evolves. How fast their critical business sectors are automated is critical for their economical survival. Speed in acquiring critical applications drive a tremendous demand for fast design of software, which in turn, exerts great pressure for capable, timely, and responsive software development projects. In addition, as time passes, and the number of business applications continue to grow, the need for upgrades further increases the demand for software maintenance, upgrade, and management. Today's customers require development of high-quality software products, on time, and at a low cost.

As a consequence, the software development industry, has exhibited a tremendous growth path. In 1993, the number of businesses in the United States that were engaged in software development activities was estimated to be in the vicinity of 32,000 businesses [Jones, 1994, p. 19]. As a Nation, we spend close to 100 billion dollars a year on development, production, and maintenance of computer software [Pressman, 1993, p. 13]. Many companies engage in producing their own software or developing products for other companies. However, industries in the United States are following an alarming

path leading to what many have called the "software crisis" [Pressman, 1993, p. 12]. Many software products consistently fail to meet cost, schedule and performance goals. For these reasons, software development has been considered a risk-prone activity [Jones, 1994, p. 46].

Numerous analytical tools and software engineering techniques, such as Computer- Aided Software Engineering (CASE) technology, have been developed to assist in software development. However, management problems continue to exist [Sprague and McNurlin, 1993, p. 272-278, and U.S. General Accounting Office, 1993]. Managers responsible for software development must have a good understanding of the complex interrelationships that take place within a software project in order to minimize risks and be successful. Many problems associated with software have been caused by the manager's lack of knowledge of important factors affecting development, identification, and project control.

Managers need to have an integrative view of the process they are trying to manage. They need to be able to study and understand the system as a whole, and not as individual interacting parts. An effective mechanism for learning a complex system and its behavior is through the use of computer modeling and simulation. From a system dynamics' point of view, the use of computer-based tools should allow the analysis of interactive simulation results, the impact that management decisions have over time, and the causes for inexplicable or counterintuitive results.

The system dynamics model of software development, created by Tarek K. Abdel-Hamid, provides a comprehensive system-dynamics model of the software development and program management worlds. The model simulates the relationship between multiple functions of the software development process and its management functions through the use of feedback or cause-and-effect loops. As a training tool, this model allows for the simulation of a complex environment by providing numerical results. However, it lacked a friendly user interface capable of providing the means to modify and examine the cause-and-effect behavior inherent in the model's information feedback loops.

B. PURPOSE OF RESEARCH

The objective of this thesis is to design and develop an effective graphical user interface implementing causal tracing. The interface design should result in a tool that facilitates the investigation of information feedback loops by allowing the user to trace back, and examine the cause-and-effect of selected variables during or after a given model simulation. A causal tracing user interface will substantially enhance the value of a system dynamic model as a learning tool, as well as provide the means for further modeling research and the study of the complexities affecting the software development and management worlds.

C. SCOPE OF RESEARCH

The research focuses on the design, development, and documentation of a graphical user interface using the Ventana Simulation (Vensim) Environment and its demonstration as a potential learning aid for software managers. Vensim is a Windows based modeling and simulation environment that provides a comprehensive set of analytical tools. This research focuses on the design considerations and prototype development of a graphical user interface that incorporates Vensim's Causal Tracing features as an investigative tool. This research expands the work on model conversion and experimental interface design completed by Captain Richard D. Davis [Davis, 1995].

D. THESIS ORGANIZATION

Chapter II discusses the current software development and project management state of affairs, the problem areas in current methods of training software managers, and the role of system-dynamic software modeling and simulation play to solve them. Chapter III will provide an overview of VENSIM salient features and capabilities.

The user interface design and architectural considerations are discussed in Chapter IV and V. In Chapter VI, the user interface is fully explained. Chapter VII provides a demonstration case of the analysis capabilities of the user interface. Chapters VIII through X summarize this research effort.

II. RESEARCH BACKGROUND

A. SOFTWARE PROJECT MANAGEMENT CURRENT STATUS

Computers, associated software, and information are an integral part of every aspect of today's society. Because corporations and the Government, especially the Defense sector, depend more and more on information systems to support their critical business functions, the role of computers and software is increasingly critical. In a computer-bound environment, the more quickly and efficiently that high-quality software can be developed, the more flexible Industry and the Government can be in responding to changes in today's dynamic and unstable world. Software is a central ingredient for success. For these reasons, the demand for software systems has shown a fast growth. However, the record of software development and project management is not good.

Examination of the current state of affairs with software development and project management reveal very disturbing facts [Jones, 1994, p. 27-61]:

- Most new systems are extremely complex due to demanding requirements during the formal requirements phase or creeping user requirements (Changes to the project requirements which occur after the formal requirements phase).
- Most projects exhibit excessive schedule pressure, as the users or management try to force the completion of the project ahead of the capabilities of the development team.
- Delivered software for projects either do not work or fail repeatedly in operation with the subsequent increase in user dissatisfaction.
- Inaccurate cost estimating of the level of effort needed result in cost overrun and time delays.
- There is a lack of fully skilled managers in software management techniques. Many managers lack the relevant experience required for proper oversight.

As a consequence, many software-driven systems are delivered late, have cost overruns, rarely meet user performance requirements upon initial delivery, and are difficult to maintain in the outyears.

An investigative report completed by Senator William S. Cohen, affirms that:

> The development and testing of large government computer programs can be as difficult to manage as any weapon systems acquisition. Like weapon systems, there is an incentive for agencies to initially focus on buying the platform —the computer hardware— rather than on software development and future personnel and operating costs. Decision makers may feel more comfortable reviewing something tangible, and agencies may push to buy into hardware before adequately thinking through what to do with it. Once the large hardware costs are incurred and the program bought into, inevitable problems with software development to tie together diverse hardware occur. At this point, it becomes extremely difficult to cancel or modify the program....Large computer acquisitions demand greater attention, because history shows that they are not being managed in the most efficient manner. Within the last four years, GAO published 74 reports on information technology programs. The reports identified problems with requirements analysis, management, cost/benefit analysis, and limited competition. [Cohen, 1994, p. 7]

Lack of relevant experience and education have been identified as a contributing factor.

> Software managers are seldom adequately trained for their jobs, and many lack even rudimentary skills in normal managerial tasks. The root cause can be traced back to inadequate curricula at the undergraduate, graduate and professional level. Many software managers do not receive adequate training in the six basic tasks of software project management: sizing, estimating, planning, tracking, measurement, and assessment. [Jones, 1994, p. 52].

All too often, managers tend to treat the symptoms to these problems and not their causes. Also, many use "gut feelings" instead of hard data to develop quick fixes to management problems [Reifer, 1993, p. 1]. The use of intuition alone is not sufficient as "sheer intuitive judgment is unreliable about how the total process will change with time, even when there is good knowledge of the individual parts of the system" [Neimeir, 1990, p. 29.2.1].

Software managers need a robust tool that allows them to learn to cope with change and uncertainty in this dynamic complex environment. The use of models and simulations provide the means for experimenting complex situations involving change in order to gain insight without the expense of studying the real systems.

B. MODELS AND SIMULATIONS

Models and simulations are necessary to understand the behavior of complex system dynamics. Such a model makes use of time-based mathematical formulations to describe the behavior and structure of systems composed of interacting feedback loops. In system dynamics, the present state of the system will depend on all its past states (i.e. organization behavior or time history).

Behavior in complex systems is molded by the way people think about the world surrounding them. Models help us to better understand world problems and to evaluate courses of action in making decisions about a system. People create mental images or models to help them reflect on problems and cope with the uncertainty of making decisions. Senge characterized these mental models as "deeply engrained assumptions, generalizations, or even pictures or images that influence how we understand the world and how we take action" [Senge, 1994, p. 8].

However, a mental image or representation of the real system is not sufficient to explain behavior. At times, our mental model is "biased, fuzzy, incomplete, inaccurate, or just plain wrong" [Austin and Ghandforoush, 1993, p. 1]. For example, the average owner of a car has a very simple mental model of how the car engine works. He can model the engine of his car as a system of related components such as gasoline, a battery, spark plugs, ignition keys, oil, gears, and pistons. The owner's mental image of how these parts of the system interact together under certain conditions, and how these interactions effect the overall behavior of the car help him deal with problems under normal operating conditions. His representation of an engine is sufficient for him to determine malfunctions in his auto. He knows that if the engine will not start, he can

attribute the possible causes of the malfunction to a dead battery or an out-of-fuel condition. [Mayhew, 1992, p. 81]

The car owner becomes helpless when his mental model can no longer explain unusual engine failures which affect the behavior of his car - the car's ability to travel. The only available recourse to him is to enhance his mental model, or get an experienced mechanic, whose mental model of an engine is more accurate and complete due to his training and experience. Owners must increase their knowledge about the system by adding the missing parts and processes needed to further understand the inner workings of the engine. His mental model needs to become more complex and complete to properly diagnose the problem and fix it.

Managers, just like car owners, must constantly modify, alter, and transform their mental model, their image of the business, to better understand how their management system's represent reality, how feedback relationships affect the dynamics and behavior of the system, and how to cope better with uncertainty in decision making. However, in the face of complex dynamic systems, the use of mental models, intuition, or perception alone is not sufficient to deal with the complexity of the management system, as "a vast body of experimental work demonstrates that individuals make significant, systematic errors in diverse problems of judgment and choice" [Senge and Sterman, 1991, p. 2]. In order to handle the complexity of dynamic managerial systems, a meticulous mathematical modeling approach and a tool to deal with its framework is needed since,

> Managerial systems contain as many as 100 or more variables that are known to be relevant and believed to be related to one another in various nonlinear fashions. The behavior of such system is complex far beyond the capacity of intuition. Computer simulation is one of the most effective means available for supplementing and correcting human intuition. [Roberts, 1981, p. 6].

Computer simulation is of great value in the study and modeling of complex systems. It can be described as tool that executes a model that imitates the real life. Simulations allow us to model large masses of data and relationships that otherwise could not be easily understood. Simulations permit the analysis of thousands of variables, many interconnected by feedback loops, as they develop over time from a given starting point.

In this way, the effects of change in the initial condition and the impact of external variables and feedback on processes can be traced. Simulations are useful in the study of complex dynamic systems. They provide the means for controlled experimentation to gain insight at a fraction of the cost of studying the real physical system through other methods.

The use of simulation technology to facilitate learning has been evident for many years. Simulations help people to change their mental models. It helps to make intuitive conclusions about complex situations. As Jensen suggests,

> Learners can be "placed" in worlds thousands of years forward or backward in time ... in "dangers" that are out of the question for real-world training and education. Science students can handle toxic and explosive materials in virtual labs ... Naval trainees can sail any day of the week through any type and level of virtual typhoon of their choosing. American pilots and tank commanders trained repeatedly in virtual worlds before embarking on real-world missions in the Gulf War. [Jensen, 1993, p.11]

Just as pilots train on how to fly an airplane under various conditions to enhance their skills and broaden their "mental model" of aircraft flying, software managers should be allowed to practice, in a software management "flight simulator," their skills in managing complex software development projects. Simulations provide the necessary tools.

C. SMFS SYSTEM-DYNAMICS MODEL

Adequate representation of the complexity of the software development and management worlds require the use of a model capable of handling a myriad of variables, relationships, and processes to properly represent them. Such a model was created by Tarek K. Abdel-Hamid using Dynamo simulation language. An integrative system-dynamics based model of the entire software development process provides the foundation for the development of the Software Management Flight Simulator (SMFS). The SMFS is a metaphor for a computer-based simulation and learning environment. It intends to provide a gaming system in which managers can acquire experience and skills

to manage software projects safely, much like the flight simulators, where pilots are trained in handling unexpected flight conditions found under bad weather without risk to the passengers or the aircraft.

The mathematical formulation provided by Abdel-Hamid captures the micro components of project management, programming, testing and productivity into a continuous view of the software development process. His approach provides a more realistic view of the interactions and dependencies between the variables of software project management. [Abdel-Hamid and Madnick, 1991, p. 12]

The model consists of four major subsystems: human resource management, planning, controlling , and software production. Figure 1 depicts a conceptual view of the model with its flows and interconnections between the subsystems.

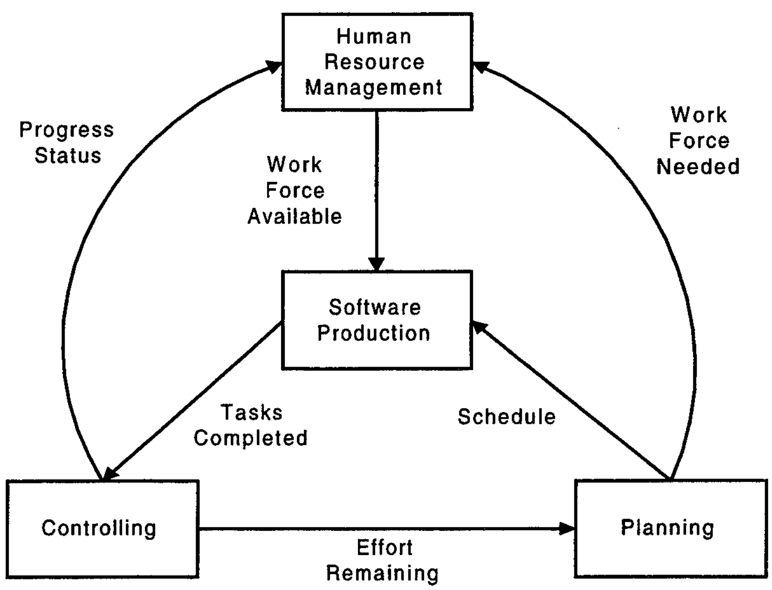

Figure 1. Software Development Subsystems [Abdel-Hamid and Madnick, 1991, p. 22]

The Human Resource Management Subsystem captures the hiring , training, assimilation, and transfer of people in the project [Abdel-Hamid and Madnick, 1991, p. 63]. The Software Production Subsystem includes the design, coding, and testing phases

of the software development process [Abdel-Hamid and Madnick, 1991, p. 77]. The Control Subsystem models the elements of measurement and evaluation functions of software project management [Abdel-Hamid and Madnick, 1991, p.117]. The Planning Subsystem models the various scheduling activities that take place during the project's life [Abdel-Hamid and Madnick, 1991, p. 129].

The model simulates the relationship between multiple functions of the software development process (e.g., design, coding, testing) and its management functions (e.g., planning, staffing, controlling) through the use of feedback or cause-and-effect loops. Figure 2 depicts a high level view of the model's subsystems cause-and-effect relationship.

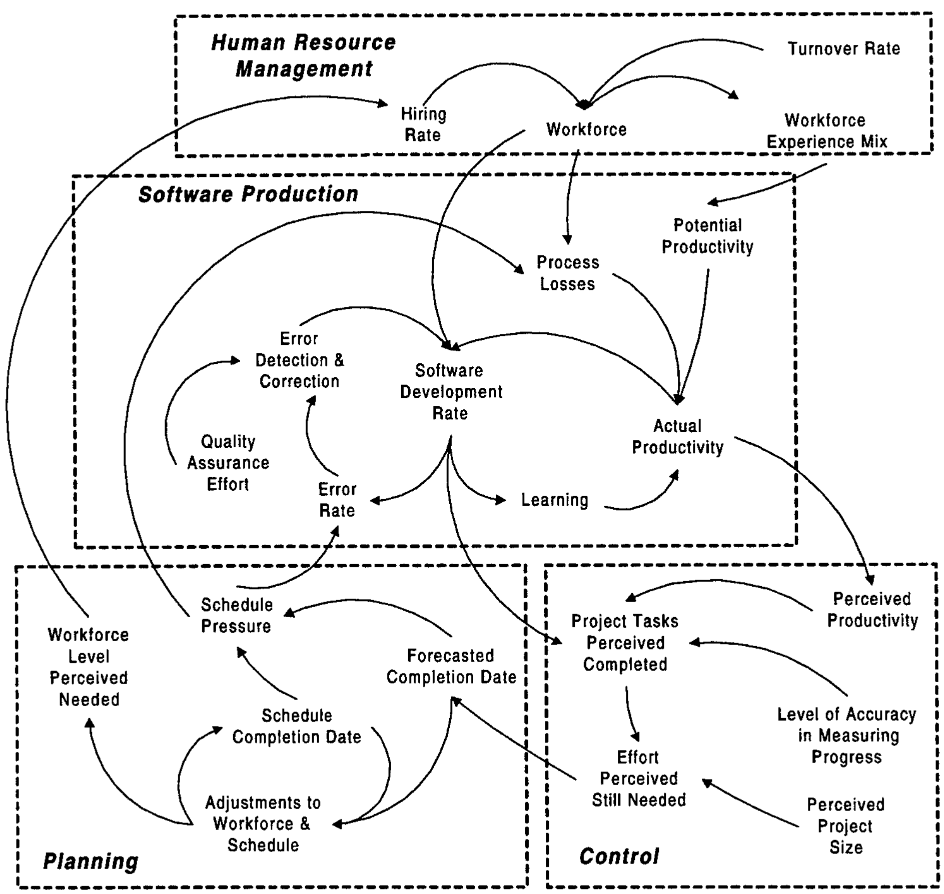

Figure 2. Causal Loop Diagram of Key Influences [Abdel-Hamid and Madnick, 1989, p. 1430]

The causal loop structures depicted in Figure 2 capture the circular relationships among cost and schedule estimates, the workforce size, and productivity through a series of feedback loops. These loops provide visibility of the many management-system's dynamic relationships that exist in a project. They also provide a continuous simulation capability for decision making. The flow of information, resources, and products used in a software project are modeled as a series of time based equations where calculations take place at discrete and small time intervals to provide numerical values as opposed to analytical results [Abdel-Hamid, 1993, p. 24].

This model provides the base needed for the development of a SMFS that, when implemented as an interactive application, allows the user to experiment with policies and strategies via games. This facilitates insight into the issues and difficulties that effect software projects without risking real projects and financial losses.

III. VENTANA SIMULATION ENVIRONMENT

A. OVERVIEW

The Ventana Simulation (Vensim) environment is a Windows-based set of tools designed to provide the means for developing and analyzing models. The environment provides all the functionality needed to define, modify, simulate and optimize models efficiently. Through the use of a suite of graphics, sketch and text editing, macro definition, analysis tools, data manipulation and optimization functions, Vensim allows greater flexibility in creating, documenting, and simulating models. Vensim allows the user to conceptualize a model in a sketch, complete the sketch by adding applicable mathematical formulations, simulate it, and present the results graphically or in table format quickly and easily.

The program is functionally divided into three components: the Workbench-Toolbox, the Sketch Tool, and the Equation Editor. The workbench is the main window from which Vensim is controlled, and which displays Vensim's main menu functions. It provides an input window for model development and output windows to display the results from analytical tools available in the toolbox. The Sketch tool is the main building tool. It allows the user to create and modify models. The equation editor allows the user to enter equations for the variables previously defined as concepts or words in the sketch diagrams. [Ventana, 1994, p. 11-12]

B. CAPABILITIES

Vensim provides an integrated environment for the development, analysis, simulation and optimization of system dynamics models. It is capable of incorporating data from external sources, providing subscripting capabilities to represent variables, and supporting the definition or specialization of functions by means of macros.

Vensim provides the mechanisms necessary to develop interfaces that allow user access and interaction with developed models. The application combines a model, or a series of models, with a user-designed and customized menu-screen-driven interface capable of

interacting and running a simulation and displaying highly formatted output data and results. A Vensim Application, or Venapps, defines the appearance and behavior of the interface by using a scripting language. Also, Vensim is capable of translating models developed in other modeling languages.

Vensim is a powerful modeling and simulation tool. It supports model building by allowing the user to sketch information or concepts in free text form. The text can later be arranged through the use of arrows to establish cause and effect among the concepts. An added feature of Vensim is that it allows the user to work with multiple views of the same problem, in which each view can show a different perspective of the problem in question.

Word and arrow diagrams establish the structure and relationship of the model in a graphical and straightforward manner. These sketches are known, within the system dynamics methodology, as causal loop diagrams. Vensim interprets these created diagrams as having a meaning. The attachment of arrows to words are interpreted as an indication of the direction of causality. They are beneficial in communicating the user's mental image of reality as a set of objects joined by unidirectional arrows, as opposed to a set of interacting equations.

The equation editor allows the user to move effortlessly from a sketch to a working simulation. The editor facilitates the documentation and mathematical definition of the concepts by using the cause-and-effect information entered in the diagrams. Vensim automatically maintains the relationships between words and arrows depicted in the diagrams and the mathematical formulations to ensure consistency. It facilitates re-arrangement and customization of models. Since Vensim keeps track of the structure of the model, it makes model building much easier and more efficient.

C. CAUSAL LOOP DIAGRAMMING AND TRACING

Causal Loop Diagramming is the act of representing graphically important system structures and processes that have loops or feedback. As explained earlier, Vensim makes the task of building causal loop diagrams easy and fast. It also allows the thorough examination and analysis of the diagrams to determine what activities, if any, are needed for a more realistic representation of the problem being modeled.

Causal loop diagrams capture dynamic situations in a visual model. The user, when brainstorming which concepts to include in his modeling definition effort, needs to think about the progression of activities, the underlying structure, and its associated dynamics. Vensim provides an excellent way of structuring this information by enabling the user to do this graphically by means of drawing tools. Once the model is represented graphically, its applicable equations can be easily established and documented through the use of the on-line equation editor.

Vensim capabilities to develop causal diagrams is not limited to new models. Existing mathematical model formulations can be imported into Vensim. Graphical tools facilitate the development of its applicable causal diagrams. Given the model is visualized, further modifications or studies of the model's cause-and effect relationships can be performed quickly.

Vensim, through the use of tools, can quickly turn causal loop diagrams into simulations. A number of structural and dataset analysis tools are included in Vensim to provide the user with information about the structure of a model and help him in the analysis of simulations. The toolbar found in the Vensim Workbench provides access to the following important tools: the tree diagram, the document tool, the loops tool, the strip graph, and the table tool.

These tools form the foundation for Vensim's Causal Tracing capability. With the tree diagram tool, Vensim can create a diagram of the cause or use of any variable. The strip diagram and table tools allow inspection of the graphs or numerical values of a variable displayed with its cause or use. The document tool displays the equation formulation of a variable, its unit of measure, and its selected values. These tools, when configured in a user interface, enable the user to quickly find his way from interesting simulation behavior to its root cause. [Ventana, 1994, p. 5]

IV. USER INTERFACE DESIGN CONSIDERATIONS

A. ABOUT USER INTERFACES

The objective of a user interface is to establish a communication exchange between the user, the computer system, and a software application capable of proving a desired functionality - what tasks must be carried out to accomplish a number of desired functions. This exchange is made through the use of dialogs in which symbols, commands, or actions give way to communications. During the course of these exchanges, each party can interrupt, ask, and correct the communication dialog. Involved in this exchange are physical devices, such as the keyboard or other input devices and display hardware, as well as the software that controls the dialog and exchange output.

The user interface plays an important role in understanding the application's underlying processes. It provides the means for the user to develop his attitude toward the application. A software application is considered to be user-friendly when a person with limited computer knowledge or experience has little difficulty using it. An application that is perceived as difficult to learn, due to inadequate or excessive functionality, or hard to interact, due to deficient interface design, will most likely frustrate the user. The result will be for users to label the application as "unfriendly" and to reject it, regardless of its computational efficiency [Ehrhart, 1990, p. 848]. Successful acceptance of the application depends on how well the provided user interface is designed to interact with the system to perform tasks.

Interaction can be achieved through command driven interfaces, menu driven interfaces, or graphical user interfaces. Command-based interfaces allow direct and to the point execution of the elements of the application by use of commands or abbreviations entered by the user. However, interfaces designed this way require the user to learn and remember a set of commands in order to execute the various elements within the application.

A menu driven interface is analogous to a restaurant menu for selecting food from a list. The available choices are listed and displayed on the screen in some logical order to facilitate the user selection of a desired item using an input device such as a keyboard or

mouse. This method is good for the inexperienced person because they do not have to memorize command instructions.

The graphical user interface is considered a more user friendly environment since it provides communication and ease of interaction between the application and the user through a graphics-oriented display and a "direct manipulation" environment. The concept of direct manipulation was coined by Shneiderman to describe an interaction style characterized by:

- Continuous representation of the object of interest;
- Physical actions or presses of labeled buttons instead of complex syntax;
- Rapid incremental reversible operations whose impact on the object of interest is immediately visible. [Shneiderman, 1992, p. 205]

A graphical user interface can accommodate the previous interaction methods easily. It combines objects such as menus, icons, dialog boxes, commands, and mouse control with rectangular work areas called windows. The use of graphics or pictures enhance the application ease of use since the user does not need to know cumbersome commands. In this type of interface, the user is able to display several windows on a single display screen. The user can manipulate text, graphics, or any other available element in any window displayed by switching among them with relative ease.

To most computer users, the software interface is the system itself. Therefore, friendly user interfaces must be able to facilitate the interaction of a set of input/output formats that the user can easily recognize have a functionality that the user can associate with his needs, and be able to engage in an easy man-machine dialogue.

B. DESIGN CONSIDERATIONS

A goal in designing interactive user interfaces is to develop a mode of communication that is both error tolerant, functional, and easily learned. With regards to user interfaces, their design should address two key questions:

What makes a user interface good?

How can, or should, a user interface be organized to be effective?

1. General Design Guidelines

Previous work in software user interface design by Mayhew [1992, p. 8-27] and Shneiderman [1992, p. 1-36] have identified and described several guidelines that affect the characteristics and aspects of any interface, and that designers should always have in mind in order to obtain well-designed user interfaces. These guidelines provide insight into several areas that must be considered for successful interactive interface design:

- what type of data is required and is relevant to the user at each step in the interface;
- how data should be presented (i.e., via text, graphics, tables, diagrams, etc.) to effectively capture the functionality of the application and ensure ease of use at the same time;
- what input devices facilities and methods, such as windowing and menus, should be provided for the users to communicate with the application;
- what output capabilities are needed (i.e., display types, hardcopy documentation, etc.);
- how flexible the interface should be designed to accommodate variations in user skills and preferences.

2. Organization Guidelines

The wide variety of human abilities, backgrounds, learning styles, and personalities pose a tremendous challenge for designers trying to organize the various interaction constructs and methods available in an application in a coherent interface. Shneiderman listed eight principles to adhere to during the design and organization of interactive interfaces [Shneiderman, 1992, p. 72] The principles are:

- Strive for consistency
- Enable users to use shortcuts
- Offer informative feedback
- Design dialogs to yield closure
- Offer simple error handling
- Allow easy reversal of actions
- Make the user sense they are in control
- Minimize short term memory requirements

Consistent organization is obtained when similar situations require similar sequences of actions from the user. The terminology used in prompts, menus, and commands should be similar to ensure the user is always aware of what to do next. The screen display should be formatted so that the various types of information, instructions, and messages always appear in the same general area. As users gain experience in interacting with the application, the interface should be able to provide the option of using key-based commands as shortcut to facilitate faster response and results display.

The interface feedback should be organized around simple messages that provide an indication of the system status from a user requested action, or as result of his inaction. The sequence of actions in an application should be organized into groupings with a beginning, a middle, and an end to prevent user disorientation. The user should not wonder where he is in the process at any time. The interface error handling or action reversal methods should have

explicit corrective actions for the user to recover from mistakes, or to return to previous states without having to restart the whole process again. The user should be able to feel in control of the interface. Unexpected outcomes are not welcomed by a user. The interface should tell the user whether the desired task was completed or not, and the reason for any processing delays.

Simplifying complex functions execution and input sequences make the interface easier by not forcing the user to remember a complicated set of code abbreviations, or command-syntax forms to efficiently control the interface dialog.

Interaction with computers is mostly carried out through a visual medium, namely the display terminal. Getting and directing the user attention are very important design and organization considerations. Chabay and Sherwood provided the following guidelines and suggestions for good, useful displays:

- Let the display determine structure - make the display central to program structure by tying data structures and programs to displays.
- Use simple displays.
- Use a judicious mix of text, pictures, and graphics.
- Highlight - emphasize most important parts of the display by means of underlining, reverse video, blinking, size, and color techniques and strategies.
- Use multiple "pages" - keep a strong content framework visible at all times by displaying several "pages" of related information in one screen display.
- Make display understandable by use of adjacency - new information should be presented near the most recently displayed information.
- Provide help and task instructions as part of its display. [Chabay and Sherwood, 1992, p. 155-186]

The manner in which information and results are displayed must be carefully organized in an interface because of the available screen's display size area. Improperly organized windows and menus can result in the user getting lost and frustrated in a multiple display system. Windows should be kept uncluttered and menu items should be organized and structured to minimize the amount of time the user needs to make a selection.

V. INTERFACE ARCHITECTURE

A. SYSTEM OVERVIEW

The SMFS was developed using the Vensim application development facilities. A Venapps or Vensim application combines a model with a set of interfacing instructions and rules for model interacting, control, display, and storage of results generated by the model simulation. The SMFS requires the use of three files in order to operate as an interactive simulation, and one file to store the results. These files are easily identified by its extensions as follows: Vensim Model File (.vmf), the Vensim Custom Definition (.vcd), the Vensim Graphics Definition (.vgd), and the Vensim Data File (.vdf).

The .vmf file contains all the equations and the relations that define the SMFS model. The .vcd files contains the necessary control information needed to run the SMFS. Specific display and format information is stored in the .vgd file. Data and simulation specific results can be found in the .vdf file. The Appendices A through C provide detailed coding and scripting information concerning the .vmf, .vcd, and .vgd files. Figure 3 depicts a high level view of the SMFS architecture.

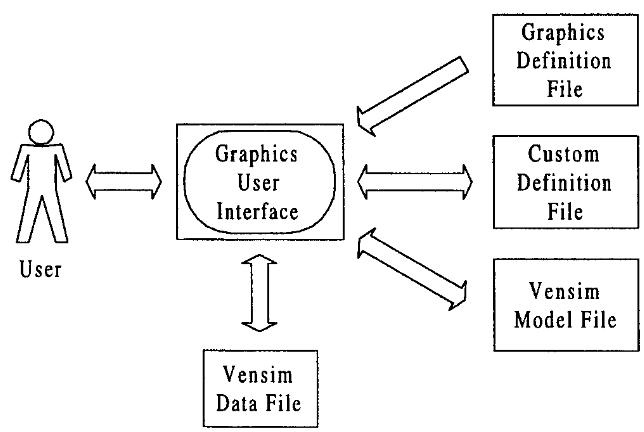

Figure 3. SMFS Architecture Overview

The user encounters a user interface upon starting the system. The .vcd file exercises the SMFS' .vmf file as a simulation, and controls the user interaction via a set of instructions in script format. The scripted instructions, separated into screen views, carry out a number of methods and functions for simulation analysis, and a set of format instructions that generate, on demand, a number of predetermined graphics, reports, and help texts from the .vgd file. Screen display sequencing and user interaction are controlled through menus and input dialog boxes, respectively. The .vdf file, created at the beginning of the simulation, stores the value of each variable, at every time interval, during the running course of the SMFS.

The SMSF interface allows the user to manipulate the values of the following selected variables at various time intervals during the course of a simulation:

- PROJDR - Project Duration
- TOTMD1 - Total Project Cost in Man-Days
- WFS1 - Staffing Level (Work Force)
- FRMPQA - Percent of Manpower Allocated to Quality Assurance

For the purpose of simulation analysis, the interface provides access to thirteen selected variables during the course of a simulation. However, this is not intended to limit the user access to variables in the model. The user is capable of accessing any variable within the SMFS' model during the execution of the provided analysis routine at any time during a simulation run. The interface will always revert the selection of variables for analysis to the following list of variables as a default starting point:

- INSPRD - Instantaneous Productivity
- PRDPRD - Perceived Development Productivity
- PRDPER - Productivity in Last 40 Days Period
- PRTKDV - Tasks Developed in Last 40 Days Period
- PRMD - Person-Days Spent in Last 40 Days Period
- FRWFEX - Fraction of Work Force Experienced

- AFMDPJ - Actual Fraction of Man-Days on Project
- COMMOH - Communications Overhead
- SDVPRD - Software Development Productivity
- DMPTRN - Daily Manpower for Training
- CMRWMD - Cummulative Rework Man-Days
- PRDFDS - Last 40 Days Period's Defect Density
- ERRGRT - Error Generation Rate

B. MENU STRUCTURE

The SMFS graphical interface is based on a menu driven dialog style network. This interaction technique was chosen because it allows inexperienced users to easily interact with the SMFS simulation. A cyclic, tree-structured menu hierarchy facilitates the execution of tasks, the display of information, and the navigation of screens within the user interface. Figure 4 illustrates the SMFS interface high level menu structure using a block diagram.

The SMFS Main Menu allows the selection of the following options: 1) Access the System Dynamics Primer, 2) View the SMFS Simulator Model Overview, 3) Play a New Game, 4) Analyze Previous Run Games, and 5) Exit the SMFS. Selection of option 1 or 2 provides to the user relevant information about the System-Dynamics theory and the SMFS model main modules. Option 4 begins a new simulation. The user is allowed to access a series of customized reports, graphs, and data tables with return to the Project control Center along the original path. The option Analyze Scenario opens a series of tools designed to facilitate analysis of the scenario at the current time interval. Upon completion of analysis, the user is returned to the Control Center screen to continue with the simulation. Menu item 4 also enables the user to load a previously run simulation file to perform post-mortem analysis. Option 5 terminates the simulation execution, closes the data .vdf file and returns the user to the initial location were the interface was first activated.

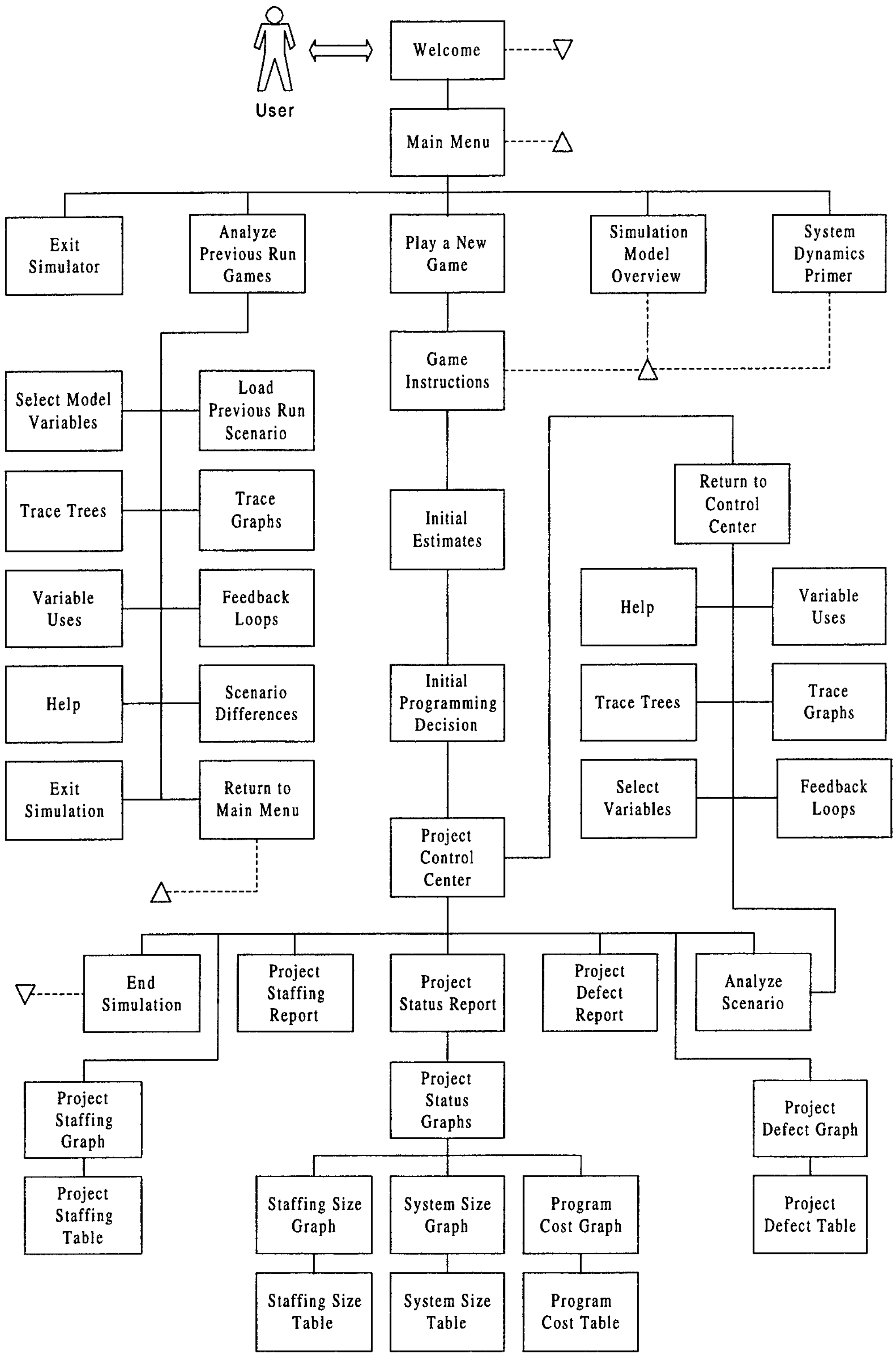

Figure 4. SMFS Interface Menu Structure

C. USER'S HANDBOOK

1. Introduction

The purpose of this manual is to allow the user of the SMFS to load, execute a simulation, and conduct analysis using the built-in features of the interface. The only assumptions that are made is that the user is working on an IBM compatible personal computer or similar system, that the user is familiar in using Windows-based software products, and that the user has the Vensim main program installed on his microcomputer.

The SMFS graphical user interface follows a menu driven format. The user is presented with a variety of choices within each menu. Selection of any menu item is accomplished by clicking the left button on the mouse, or by depressing the ALT key together with the first letter of the label identifying the menu item selection. The user has a series of exit options. Their access depends on where he is located with respect to the simulation execution. The user has the ability to quit the ongoing simulation and return to the Vensim workbench or to the Windows environment, depending on were the SMFS simulation was first initiated, return to a previous menu within the simulation, or exit in order to initiate a new simulation game via the interface.

2. System Requirements

The SMFS requires the following hardware and software for execution:

- An IBM 286 compatible computer or better running MS-DOS and Microsoft Windows 3.1 or higher, with a mouse system. For large model simulation, a 386 or better computer, with math coprocessor is recommended.
- Two Megabytes (MB) minimum RAM (four MB minimum required for large model simulation).
- A hard disk with 1.6 MB of available space for the Vensim program files minimum installation, 6 MB of disk space required for full installation.
- Vensim Professional DSS Simulation Environment, Version 1.61.
- Floppy Disk containing interface files Causal.vmf, Causal.vcd, Causal.vgd; and auxiliary files Base.vdf, Causal.vts, Vskt0000.bmp and Vskt0001.bmp.

3. Interface Starting Methods

Before you can start the SMFS interface, the files residing in the floppy disk must be copied to a working directory on the hard disk. The current version of Vensim will not load and execute simulation files stored on floppy disks. Vensim requires that these files be stored in the hard disk because it uses and creates a number of different files at once during simulation execution. Use Windows to create a directory beforehand and to copy the files to it. Once the working directory has been created with the applicable files, the user can launch the Vensim environment.

Once the Vensim environment is active, the user can activate the interface by way of one of two methods available. The first method assumes the user is performing editing work in the Vensim workbench area. To run the simulation interface from the workbench, the user must load first the Causal.vmf and the Causal.vcd files. Vensim Applications (Causal.vcd) require that the simulation model file (Causal.vmf) be active in the background for proper execution.

To load the Causal.vmf file, select **Open** from the **File** pull-down menu and select the file by double clicking on it. The SMFS Interface requires that the Causal.vmf file be displayed in the sketch mode. If the file is loaded in the text mode, select **View** from the pull-down menu and choose **Sketch** to change its view. To load the Causal.vcd file, press on the VCD button located at the bottom of the vertical toolset. This action displays a **Name of File to Edit** dialog box with a list of applicable filenames in a selection box. Select Causal.vcd by double clicking on it with the left mouse button. At this point, the two loaded files will be displayed (Figure 5), and the user is ready to start the SMFS Interface. From the File pull-down menu, select **Run App Int** option to activate the interface.

A variation of this method is obtained when the user selects **Open** from the **File** pull-down menu and select the .vcd radio button to change the filename type displayed in the selection box. By double clicking with the left mouse button on the Causal.vcd file, the Causal.vcd file will be automatically loaded along with the model file, and activated

immediately. With these methods, the user can return to the Vensim workbench to perform editing on the simulation files.

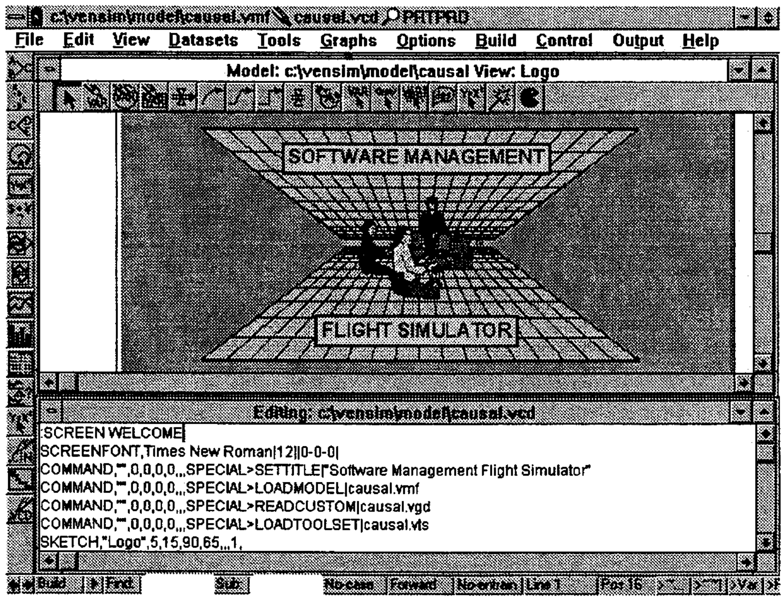

Figure 5. The Vensim Workbench Environment

The second method to activate the SMFS interface is to have an icon configured to by-pass the workbench and launch the SMFS Interface automatically by double clicking on it. The easiest way to create the icon is to copy the Vensim icon to its program group by use of the Windows Program Manager's File>Copy command. Once copied, and using the Windows Program Manager's File>Property command, change the icon's properties as follows:

- Description: SMFS Interface
- Command Line: C:\Vensim\Vensim.exe /Vensim\model\Causal.vcd
- Working Directory: C:\Vensim\Model
- Short Cut Key: None

Once the changes have been made and the modified icon is saved, the interface is ready to be activated directly from the Vensim program group. This method is the recommended way to install and initiate the simulation interface because it will effectively prevent accidental modification by users by denying access to critical interface files.

4. Running the Simulation

Once the user interface is activated, the user is ready at this point to start a simulation or game. The SMFS Interface displays a welcome screen and waits for the user to initiate the game. The user is then presented with the menu screen shown in Figure 6. From this menu, the user can select an option from five choices available. The first four selections produce secondary menus with multiple options, as depicted in Figure 4. The fifth option terminates the simulation, and, depending on the method used to launch the interface, sends the user back to that starting location.

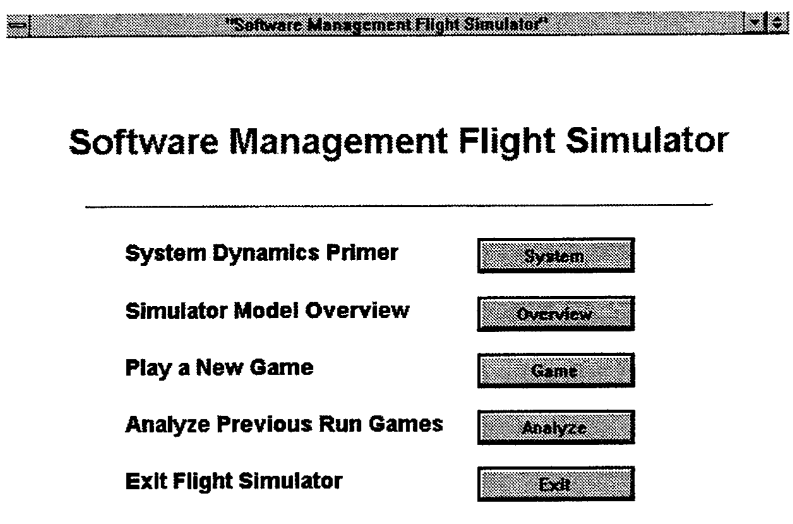

Figure 6. SMFS Main Menu

a. System Dynamics Primer

This menu item provides the user with concise information about System Dynamics' theory, principles, and notation formats. The option intends to provide background about the underlying theory used in developing the SMFS model. When the user selects this option, the interface presents the menu displayed in Figure 7.

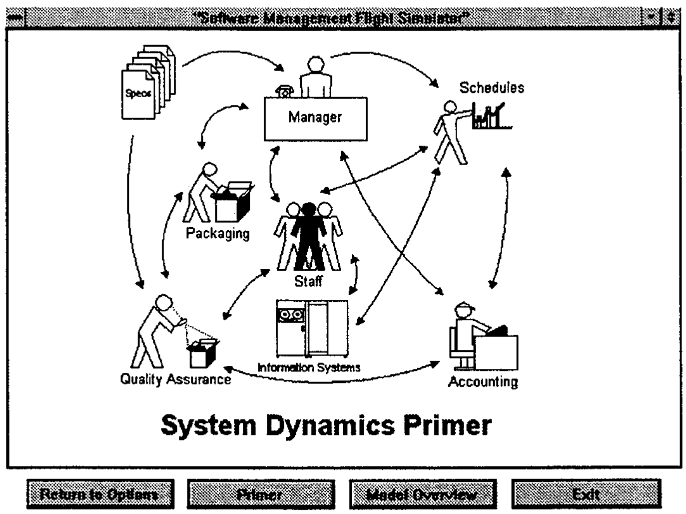

Figure 7. System Dynamics Primer Menu Display

Clicking the **Primer** button displays a Vensim window allowing the user to print the information presented or to export the contents of the window. Clicking **the Model Overview** button causes the Simulator Model Structures menu to be presented. The **Return to Options** will take the user back to the main menu display, while the **Exit** Button will cause the interface to stop the current game and return the user to the location where the interface was first activated.

b. Simulator Model Overview

This option displays the Simulator Model Structure screen, which contains a menu of choices that allow the user to individually select and familiarize with any of the subsystems, sectors, or subsectors that, when exercised together, form the heart of the SMFS model simulation. The user can access any of the model structure's causal diagram, as well as display a Vensim window with details about the structure's particular behavior. For example, if the user decides to choose the **Human Resources Subsystem** option by clicking its button, the display shown in Figure 8 will be presented.

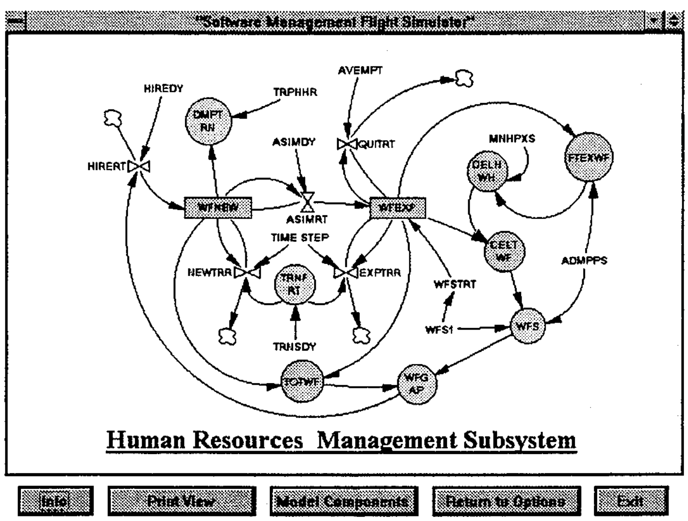

Figure 8. Human Resources Management Subsystem Structure

Every option available in the Simulator Model Structure menu presents similar screens that contain the applicable causal diagram for the component in question, and the button bar shown at the bottom of Figure 8 above. The **Model Component** button allows navigation through the model structures without having to return back to previous screens. The **Print** buttons will display a print dialog box to print the causal diagram. The **Info** button displays a Vensim window with information about the structure being reviewed. The **Return to Options** and **Exit** buttons are mechanisms to return back to the main menu of the interface, or to terminate the simulation and leave the interface.

c. *Play a New Game*

This option causes the SMFS interface to initiate a new simulation by displaying a filename dialog box and requesting the user to enter a filename for the simulation data file (.vdf). The user has the option of typing a new name, or reusing a previous filename. A series of sequential screens are presented to the user to provide instructions and game background about the particular situation being simulated. The user is then requested to make his first decision by entering values for the staffing level desired and what percentage of it should be allocated for QA purposes. The interface then proceeds to present the Control Center display (Figure 9), the location where the user will control the ongoing simulation until completion.

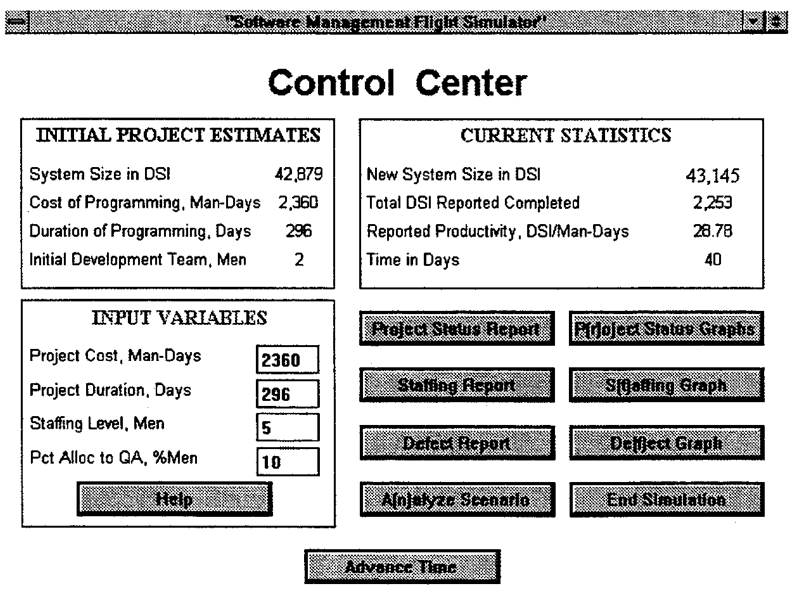

Figure 9. SMFS Interface Control Center

The Control Center screen is divided into four information and control areas. The top two panels display information concerning the simulated software project and the current statistics of the project. The third panel, on the left, allows the user to enter his decisions concerning key project metrics under his control. The fourth area

presents a series of buttons that give access to a series of pre-defined custom reports, data tables, graphs, and access to the SMFS analysis capabilities. The user advances the simulation in increments of 40 days by clicking the **Advance Time** button.

The simulated software project prevalent situation at a given period of time must be analyzed to determine what decisions must be made to maintain the project under cost and schedule control. The user determines what his next decisions will be by reviewing the available reports (Figure 10), graphs, or by use of the provided analysis functions. The details of the **Analyze Scenario** button will be presented in the next section. The user enters his decisions in the Input Variable panel and advances the time to the next reporting time period. The user repeats this process until the Project Status Report indicates the Percent Delivered Source Instructions Reported Complete equals 100% or the Game Over dialog box appears. At the completion of the simulation, the user selects **OK** to close the dialog box, then clicks the End Simulation button to return to the beginning of the SMFS.

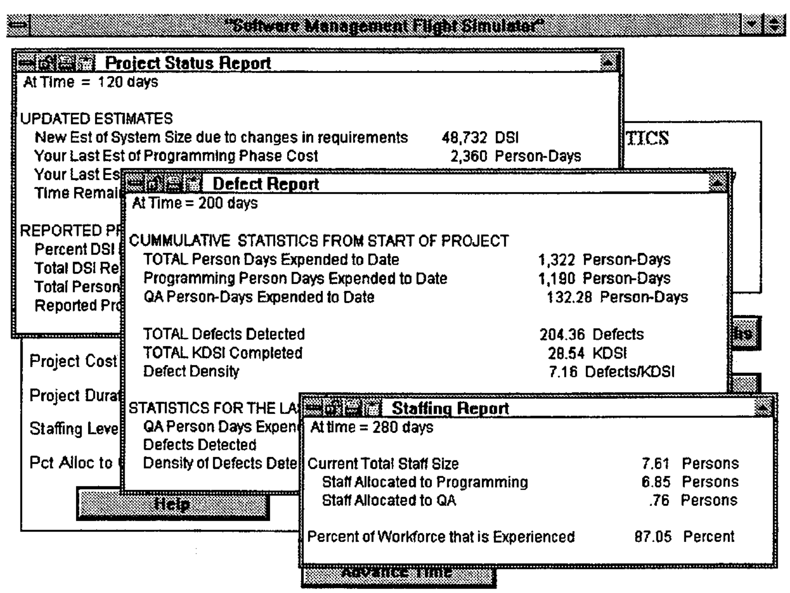

Figure 10. SMFS Report Examples

d. Analyze Previous Run Game

Selection of this option causes the SMFS interface to display the Simulation Post-Analysis menu screen (Figure 11), which contains a series of commands and choices set to assist the user in performing analysis.

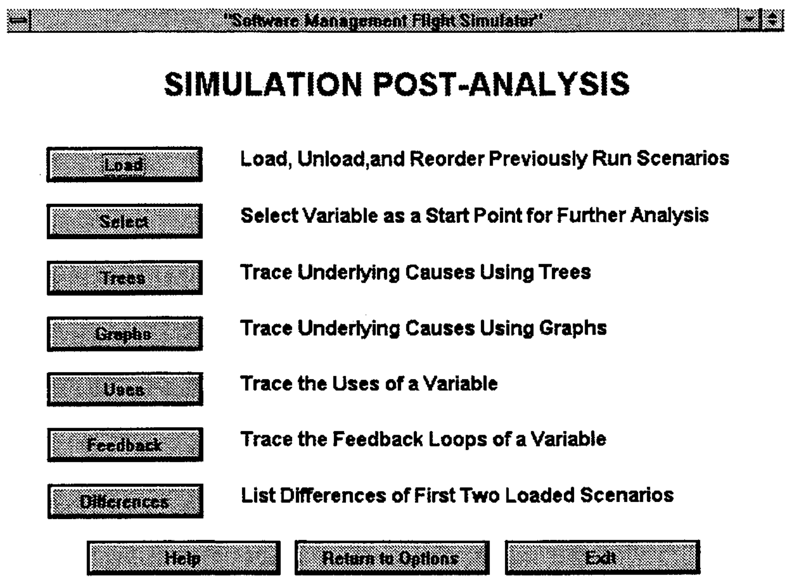

Figure 11. SMFS Post-Analysis Capabilities

The purpose of this option is to facilitate the loading of up to eight stored simulations or games, and to enable the user to study and make performance comparisons between these simulation runs to determine particular behavior tendencies. Even though the user can load up to eight scenarios at a time, it is recommended that no more than four be loaded at any given time since it becomes difficult to read graphs with more than four scenarios loaded if you have a small monitor display.

In order to conduct post-analysis of games, the user must load a previously run game. Once it is loaded, the user can easily perform analysis of the output. The user will load in any previous games by clicking on the Load button. This action will display a Load and Reorder Previous Scenarios dialog box, which displays the names of

previously saved games. This command will display two filename lists. On the left box is a list of loaded scenarios and on the right is a list of scenarios that are stored. The user can select/deselect the game of interest by following the steps below:

- The << button loads scenarios. Click on the scenario you want to load in the right hand list, and then click the << button. If you do not have a mouse available, use the TAB and Return (or Enter) key combination to move among the boxed selection items and to make your selection.

- The >> button unloads scenarios. Click on the scenario you want to unload in the left hand list, and then click on the >> button. If the list on the right is empty, you will need to run some simulation games. You can do that by exiting to the main menu and selecting to run a game.

The **SELECT** option allows the user to select a variable of interest for analysis (other than the default variable, which is the active variable at the time the simulation was last terminated.). A Variable Selection dialog box that contains a list of variable names in the current model will be displayed. The user can make his selection by scrolling down the list and double-clicking on any variable on the list, by clicking on the variable of interest and then clicking on the **SELECT** button, or by typing in the space provided the name of the variable and then clicking the **SELECT** button.

As previously discussed in Chapter III, Causal tracing is a process that assists the user in determining the underlying causes of model behavior, and the differences in behavior between different scenarios. There are four options available for doing causal tracing. They are:

- **Tree** - This option enables the display of the causes of the variable of interest, as a tree network that branches from the right. Variable that are shown between parenthesis to indicate that they appear somewhere else in the tree. Also, this option displays a graphical representation of the variable of interest. An option menu is provided for the user to continue further analysis.

- **Graph** - this option is a refinement of the Tree option. It allows the display of the equation and other pertinent information of the variable of interest, and the graphical display of a predetermined set of variable levels affecting the variable of interest. An option menu is provided for the user to continue further analysis.

- **Uses** - This option enables the display of the uses of a variable as a tree network branching from the left. Variables are shown between parenthesis to indicate that they appear somewhere else in the tree. Also, this option displays a graphical representation of the variable of interest. An option menu is provided for the user to continue further analysis.

- **Loops** - This option displays a list of all feedback loops passing through the variable of interest. The list is ordered from the shortest loop (the one involving the least number of variables) to the longest loop. Loops provides useful information about model interactions. Also, this option provides useful information about the variable of interest. An option menu is provided for the user to continue further analysis.

Each of these options present the user with a menu selection of their own to allow the user to select a different variable of interest and switch "on the fly" between the various causal tracing available functions to study the variable characteristics and behavior. Figures 12 through 15 provides display examples of these options.

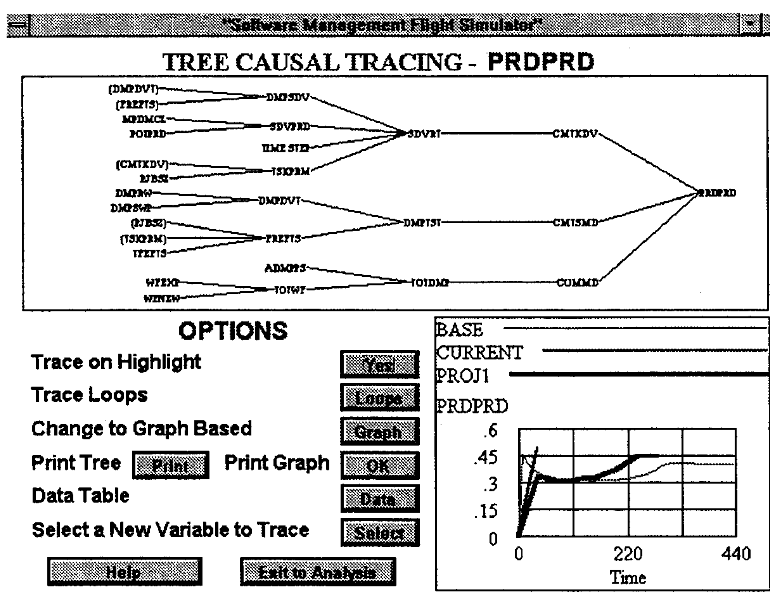

Figure 12. SMFS Post-Analysis Tree Causal Tracing Example

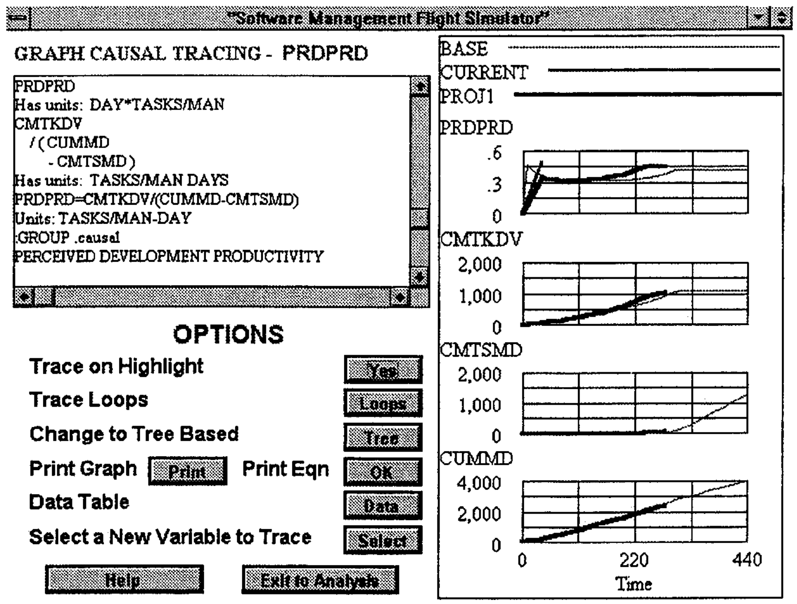

Figure 13. SMFS Post-Analysis Graph Causal Tracing Example

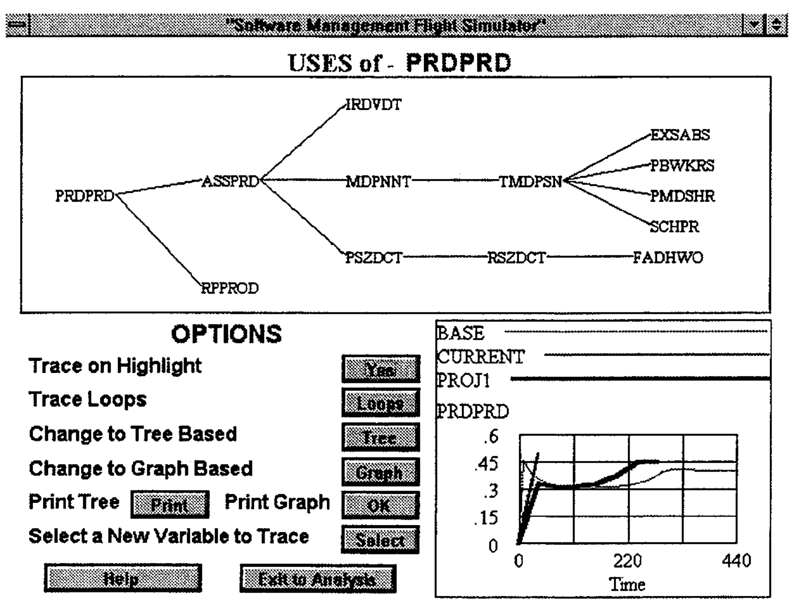

Figure 14. SMFS Post-Analysis Uses Causal Tracing Example

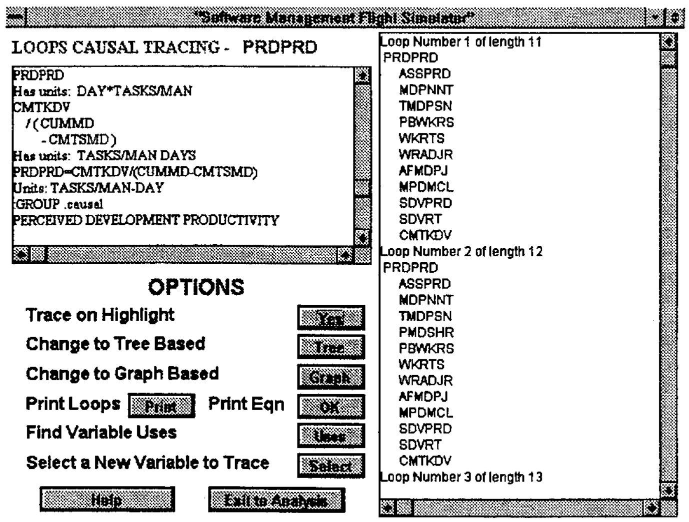

Figure 15. SMFS Post-Analysis Loop Causal Tracing Example

The cumulative functionality designed in these options is described below:

- **Tree**, **Graph**, **Uses**, and **Loops** causal tracing utilities, as previously discussed.

- **Data** - This option enables the display of a Vensim Window of the numerical values of the variable of interest and its causes in a table format by time periods. This window can then be printed, its content copied to the Windows clipboard, or deleted when no longer needed.

- **Print** - This command let the user print applicable **Tree**, **Graph**, and **Loops** outputs and the equation and other related information about the variable under causal tracing.

- Trace on Highlight - This option enables the user to change the variable of interest by clicking on any variable displayed in the tree or uses network, graphics, or loop listing, to highlight it. Clicking on the **Yes** button causes the interface to present the new variable of interest and the respective **Tree**, **Graph**, **Uses**, or **Loops** display, depending on where the user selected to make the change.

- **Select** - this option allows the user to change the variable of interest by choosing from a list, as previously discussed earlier in this chapter.

- **Help** - This option will cause a Vensim window to be displayed with instructions and concise information about the functionality of the options available at that particular screen display. The window contents can be sent to a printer or copied to the Windows' clipboard.

- **Exit to Analysis** - This item allows the user to return back to the Post-Analysis screen menu.

The **List Differences** option allows the user to make comparisons of the initial constants used by the various loaded games or simulations by means of a table of numerical values. The user, at his discretion, can print this table or opt to return back. The **Help** option will present Vensim information window about the menu items and provide instructions on how to use them. The information contained in this window can be printed, copied to the Windows clipboard, or deleted when no longer needed. The **Return to Option**, when activated, causes the interface to return the user to the main SMFS menu screen, or to terminate the application, respectively.

It should be noted that the analysis capabilities described in this section are, with a few exceptions, identical to the analysis capabilities contained in the **Analyze Scenario** module described in paragraph 4.c above. The differences are as follows:

- The Simulation Analysis menu that is controlled by the **Analyze Scenario** button is designed to force the user to terminate the game at the control Center screen always. The Simulation Post-Analysis menu provides facilities to exit the simulation or to initiate a new game directly.

- The option for **Selecting a New Variable** in the Simulation Analysis Menu has been fixed to the variables listed in Figure 16 in order to focus the user's initial analysis of the situation. The user still has access to any variable in the model by using the Trace on Highlight command available in the **Tree**, **Graph**, **Uses**, and **Loops** causal tracing function facilities. The Simulation Post-Analysis menu makes use of a dialog box to provide global access to the variables in the model.

- The Simulation Analysis menu does not have the following items available: Load, Unload, and Reorder Previously Run Scenarios and the List Differences of First Two Loaded Scenarios.

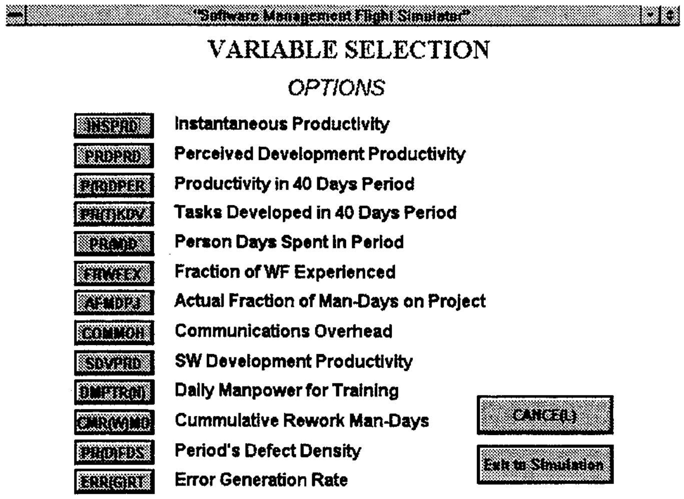

Figure 16. Variable Selection Menu

e. Exit

The **Exit** button will cause the SMFS application to terminate its execution and return the user to the initial activation environment. Depending on the method in which the SMFS Interface application was first launched, the user will be returned to either the Vensim workbench or the Windows program manager.

5. Simulation Results Storage

The simulation's initial data and game results are stored by the Vensim environment as datasets, in Vensim Data format (.vdf). When the user selects to play a new game from the menu, the SMFS will ask the user to input a filename. This filename is important because it will contain all the initial data used to activate the simulation, as well as the results of the user interaction with SMFS interface. This files are saved using a Vensim specific format. The files can not be examined or modified via a text editor. The Vensim workbench has facilities to manually load, manipulate, and export the results contained in a .vdf file. The Post-Analysis facilities of the SMFS interface allow the user to only load these files for display and later study.

42

VI. CAUSAL TRACING DEMONSTRATION

A. INTRODUCTION

This chapter will provide a demonstration of the utility of the SMFS interface by simulating two scenarios of equal size to investigate the impact of different staffing profiles on project performance. The scenarios, Project 1 and 2, focus on executing different hiring policies while keeping other variables under the manager's control constant. The simulation results are compared and the applicability of Brooks' Law is investigated using the SMFS post-analysis causal tracing facilities.

B. INITIAL CONDITIONS

Once the SMFS is initiated, the manager receives the project's initial estimates and available staffing level. In both scenarios, at the start of the project, the manager is informed that a project of 42,879 Delivered Source Instructions (DSI) is to be completed in 296 days. The manager must determine the number of people he desires to hire initially and what percentage of the total staff hired will be set aside to perform quality assurance tasks. The initial estimate of staff size is determined by dividing the estimated value of effort needed in person-days (pd) by the value of the development time, in days. The initial estimate for the effort needed to complete the project is provided by the following Constructive Cost Model (COCOMO) equation for medium sized project:

$$\text{Effort} = 2.4 \times (\text{KDSI})^{1.05} \ \text{(pd)} \qquad (1)$$

Assuming 19 working days in a calendar month, the effort needed for developing and testing a project of 42,879 DSI (42.879 KDSI) is:

$$\text{Effort} = 2.4 \times 19 \times (42.879)^{1.05} = 2360 \text{ pd} \qquad (2)$$

The initial number of people needed is calculated as:

$$\text{Number of people} = \text{Effort} / \text{Time to develop} \qquad (3)$$
$$= 2360 / 296 = 8 \text{ people}$$

Once the initial effort needed is calculated, the manager is ready to make his first staffing decision and continue his simulation. The SMFS gaming interface allows the

manager to vary the estimate of the effort skill needed, the schedule, the staff level, and the percentage of staff to allocate to quality assurance in future reporting periods. Only the staff level will be allowed to change in each reporting period. In both scenarios, the management will maintain ten percent of the staff performing quality assurance tasks for the duration of the project, the effort needed at 2,360 person-days, and the time to develop the project to 296 days. The manager's challenge is to accomplish the project under these conditions by only varying the level of staff in the project.

C. SIMULATED PROJECT BEHAVIORS

Both scenarios are started by hiring eight people. As time progresses, the manager monitors the project's behavior by making use of the graphs, data tables, and pre-determined custom reports in the Control Center screen of the SMFS interface. By monitoring the project's reported size in DSI, the number of DSI completed, the reported productivity, and the effort expended, the manager can determine how much progress the project has achieved and what additional effort is needed to complete the project within the given constraints.

New project tasks are reported as better understanding of the requirements are achieved by the people working on the project or because of user-directed specification changes. These new discovered tasks may or may not generate an adjustment to the current project's level of effort and schedule estimates. As a consequence, the staffing level required to accomplish the added work may or may not be increased as time progresses. Before hiring new people, managers take in consideration the ability of the experienced staff members to absorb (for example, in terms of orienting and training, both technically and socially) new employees. As new people are added, the project productivity drops because newcomers' training is usually carried out by the project staff, reducing the staff own productivity as result. These considerations influence the manager decision of when to hire people and at what level. [Abdel-Hamid, 1989, p. 114]

1. Project 1

In this scenario, management is willing to increase the staff level to meet the project's schedule. As the project approaches its completion date, the manager realizes that the project can not be completed in the time left and with the current staff. As result, at day 240, the manager hires more people. Considering the current project size, the reported productivity, the number of DSI completed, and the time left, he determines he must double the current staff (from eight to 16 persons) in order to finish the project on schedule. On completion, this scenario delivered 64,000 DSI (a 49% increase) in 2,597 person-days (a 10% increase) and 320 days (a 8% increase). Details of the simulation results reported by the SMFS's pre-defined reports are summarized in Table 1.

	Report Period, days								
	0	40	80	120	160	200	240	280	320
Initial Project Duration, days	296	296	296	296	296	296	296	296	296
Project Effort Budget, pd	2360	2360	2360	2360	2360	2360	2360	2360	2360
Project Staff Levels, p	2	8	8	8	8	8	16	16	16
Estimates Reported									
Reported Size, DSI	42879	43210	44832	48732	55667	60859	63306	63962	64000
Reported Progress									
% Complete DSI	0	7.71	18.02	28.57	37.04	46.90	62.52	85.26	97.60
Completed DSI	0	3331	8078	13923	20621	28542	39580	54532	62467
Effort Expended to Date, pd	0	165.84	425.08	716.59	1018	1322	1627	2049	2597
Reported Productivity	-	20.09	19.00	19.43	20.26	21.57	24.31	26.65	25.31
Staff Levels									
Total Current Staff Size	2	5.71	7.03	7.46	7.59	7.62	7.62	12.66	14.44
Programming Staff	1.8	5.14	6.33	6.71	6.83	6.86	6.86	11.39	13
QA Staff	0.2	0.57	0.70	0.75	0.75	0.76	0.76	1.27	1.44
% Experienced, Reported	100	49	58	69	77	82	85	62	68

Table 1. Simulation Statistics for Project 1

2. Project 2

In this second scenario, the manager perceives the project to fall behind schedule because of the gradual increase in the project size. However, the manager, as a firm believer of Brooks' Law, opted not to increase the staff level. In this case, the manager decides to maintain the staff level constant at eight persons during the late stages of development to avoid the negative impact that communications and training overheads have on software development productivity. As a trade-off, he rather relaxes the development schedule. On completion, this project delivered 64,000 DSI (a 49% increase) in 2,541 person-days (a 8% increase) and 360 days (a 22% increase). Details of this simulation's results, as reported by the SMFS's pre-defined reports, are summarized in Table 2.

	Report Period, days									
	0	40	80	120	160	200	240	280	320	360
Initial Project Duration, days	296	296	296	296	296	296	296	296	296	296
Project Effort Budget, pd	2360	2360	2360	2360	2360	2360	2360	2360	2360	2360
Project Staff Levels, p	2	8	8	8	8	8	8	8	8	8
Estimates Reported										
Reported Size, DSI	42879	43210	44832	48732	55667	60859	63306	63957	64000	64000
Reported Progress										
% Complete DSI	0	7.71	18.02	28.57	37.04	46.90	62.52	82.48	93.67	100
Completed DSI	0	3331	8078	13923	20621	28542	39580	52754	59950	63320
Effort Expended to Date, pd	0	165.84	425.08	716.59	1018	1322	1627	1932	2236	2541
Reported Productivity	-	20.09	19.00	19.43	20.26	21.57	24.31	27.3	27.26	26.87
Staff Levels										
Total Current Staff Size	2	5.71	7.03	7.46	7.59	7.62	7.62	7.61	7.60	7.60
Programming Staff	1.8	5.14	6.33	6.71	6.83	6.86	6.86	6.85	6.84	6.84
QA Staff	0.2	0.57	0.70	0.75	0.75	0.76	0.76	0.76	0.76	0.76
% Experienced, Reported	100	49	58	69	77	82	85	87	88	89

Table 2. Simulation Statistics for Project 2

In summary, both hiring policies resulted in projects that were underestimated, late and overbudget. Project 2, the project having a constant, stable staff over the entire period of development was finished later than Project 1, the scenario that had more people added later. These results describe a behavior that is not consistent with what Brooks' Law, which states that adding people to a late project delays the project further. To investigate the reasons why this happens, the causal tracing tools available in the SMFS were used to explore the impact that these hiring practices had on productivity.

D. CAUSAL TRACING

By using the SMFS' Simulation Post-Analysis tools (Figure 11), the two cases can be easily loaded for comparison. Once the two scenarios are loaded, we must select what variable of interest we want to investigate. Since managers assess progress by evaluating productivity, the variable **INSPRD** (Instantaneous Productivity) is selected as a starting point. Clicking on the **Tree** button in the Simulation Post-Analysis screen displays the causal tree and the graph for **INSPRD** (Figure 17).

The **INSPRD** graph indicates that productivity fell at the beginning of the projects and then rose steadily, as the projects progressed in time. After peaking toward the end of the coding phase, the productivity of both projects decline at different rates. From the causes tree, the manager can observe that the results of this variable depends directly on two other variables: **SDVRT** (Software Development Rate) and **TOTDMP** (Total Daily Manpower). Also, from the causal tree, notice that **INSPRD** is affected indirectly by the behavior of variables found within three additional levels. A printout of the causal tree can be obtained easily from this screen. The printout can be used as a quick "road map" guide for further causal tracing. To examine behavior, click on the **Graph** button to display the direct causes of **INSPRD** in graphical form (Figure 18).

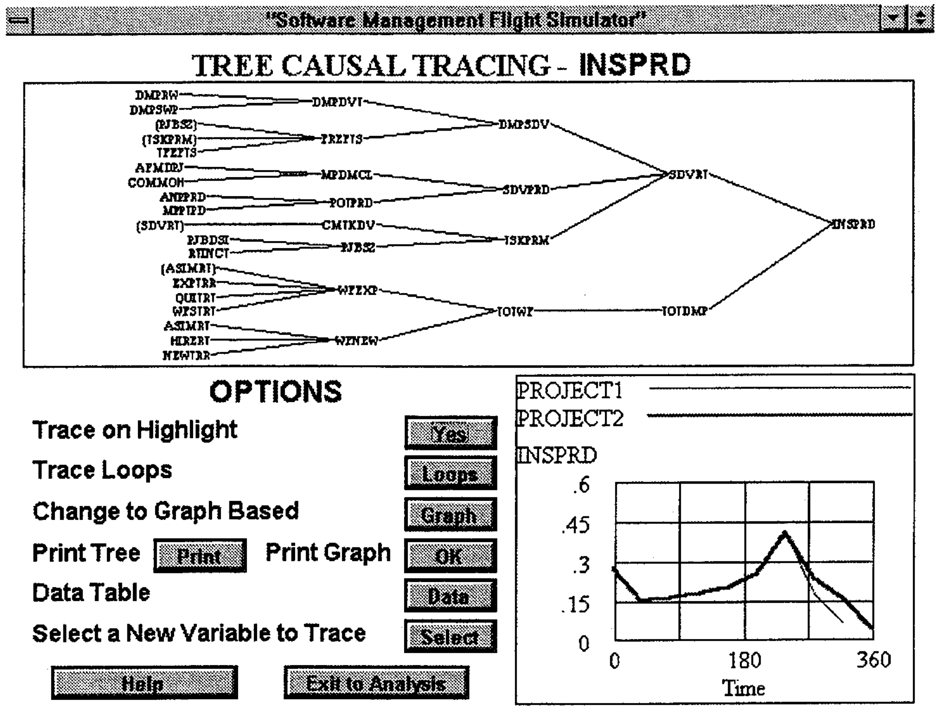

Figure 17. Instantaneous Productivity Tree Causal Tracing

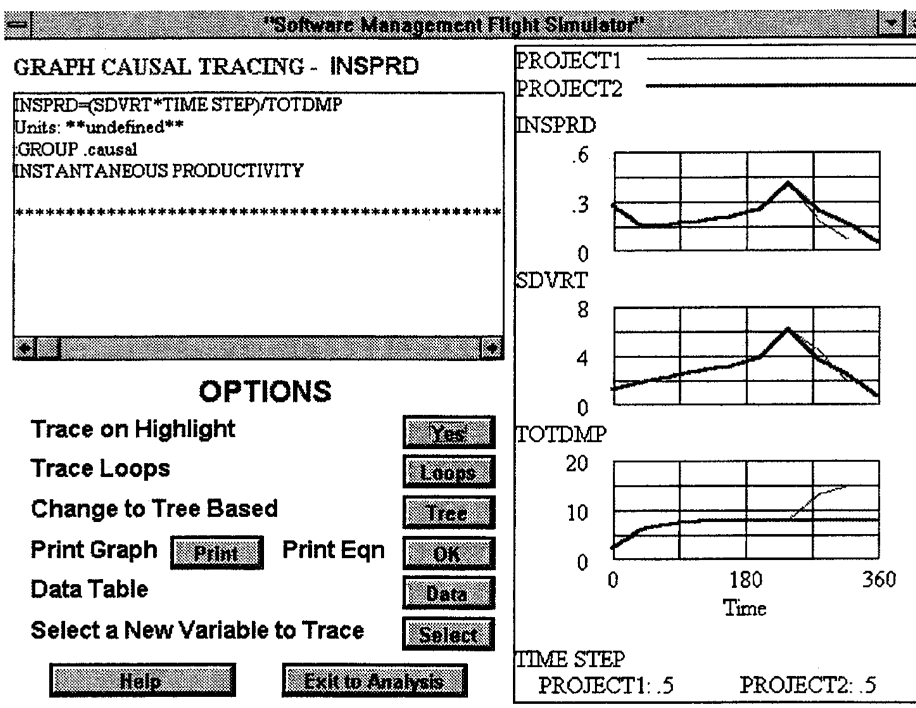

Figure 18. Instantaneous Productivity Graph Causal Tracing

In this screen, it is observed that the Software Development Rate increases as the Total Daily Manpower increases with time. **INSPRD** decreased initially because Total Daily Manpower (the denominator) increases at a faster rate. Toward the end, the Software Development Rate slows down as we add more people to Project 1, while Project 2 decreases at a faster rate. To further investigate this behavior, we select the **SDVRT** variable, and click the **Tree** button to display its associated causes (Figure 19). Using this tree as a road map, and by using the **Graph** Button to examine **SDVRT** behavior, we obtain the set of graphs shown in Figure 20.

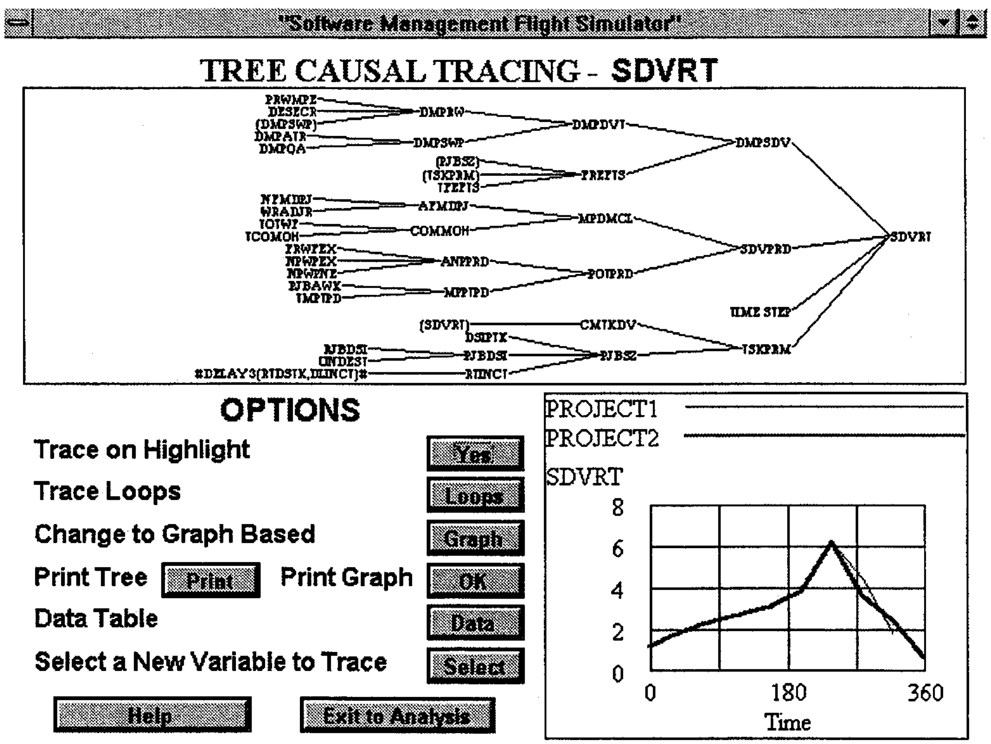

Figure 19. Software Development Rate Tree Causal Tracing

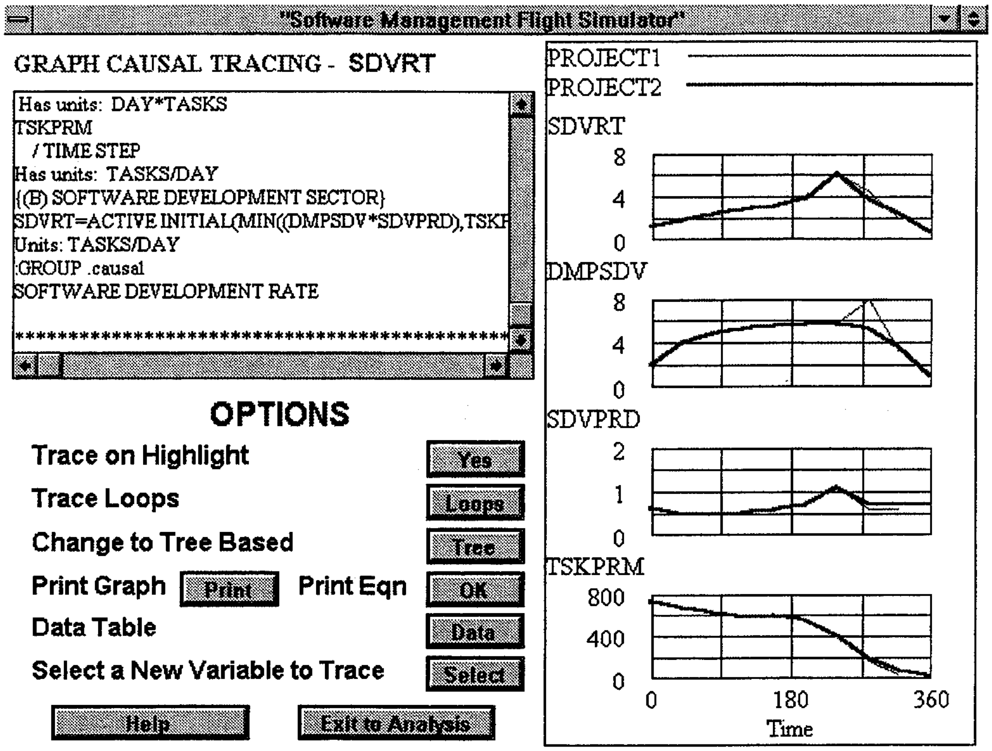

Figure 20. Software Development Rate Graph Causal Tracing

Since we are interested in productivity and its causes, select the variable **SDVPRD** (Software Development Productivity), one of the causes of **SDVRT**. From the graphs in Figure 21, **SDVPRD** is dependent on the behaviors of **MPDMCL** (Multiplier to Productivity due to Motivation and Communication Losses) and **POTPRD** (Potential Productivity).

The **MPDMCL** indicates an equal increase in motivation and communications overhead for both projects. By tracing back **MPDMCL** (Figure 22), **AFMDPJ** (Actual Fraction of a Man-Day on Project), and **COMMOH** (Communications Overhead), its behavior can be easily inspected. Causal tracing of **AFMDPJ** results in the set of graphs shown in Figure 23. Its behavior is mainly dependent on **WRADJR** (Work Rate Adjustment Rate). The **WRADJR** graph suggests that, as the projects approach the end of the coding phase, people tend to work more hours in an attempt to bring the project back on schedule to meet its deadline. This additional effort causes the MPDMCL to increase and positively affect the projects' SDVPRD.

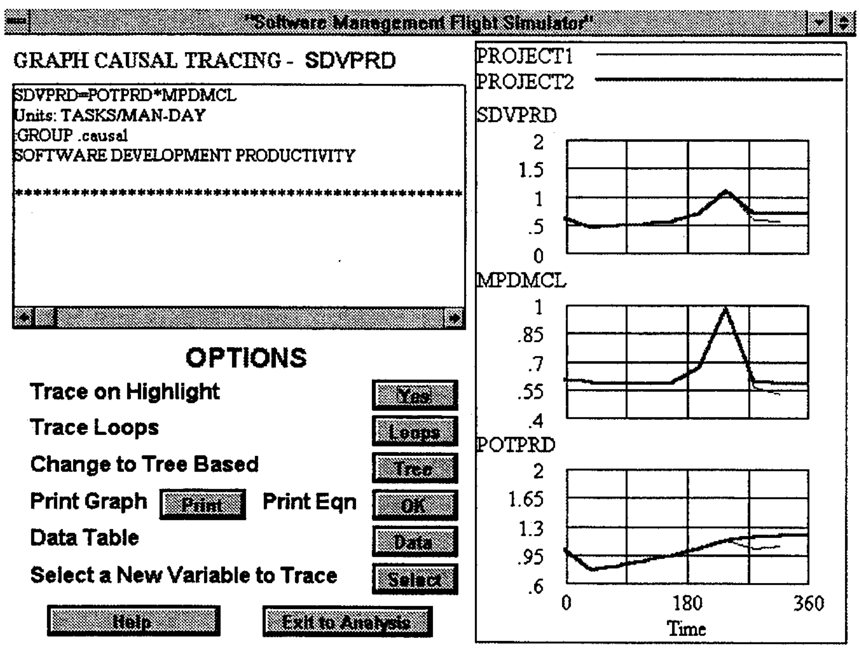

Figure 21. Software Development Productivity Graph Causal Tracing

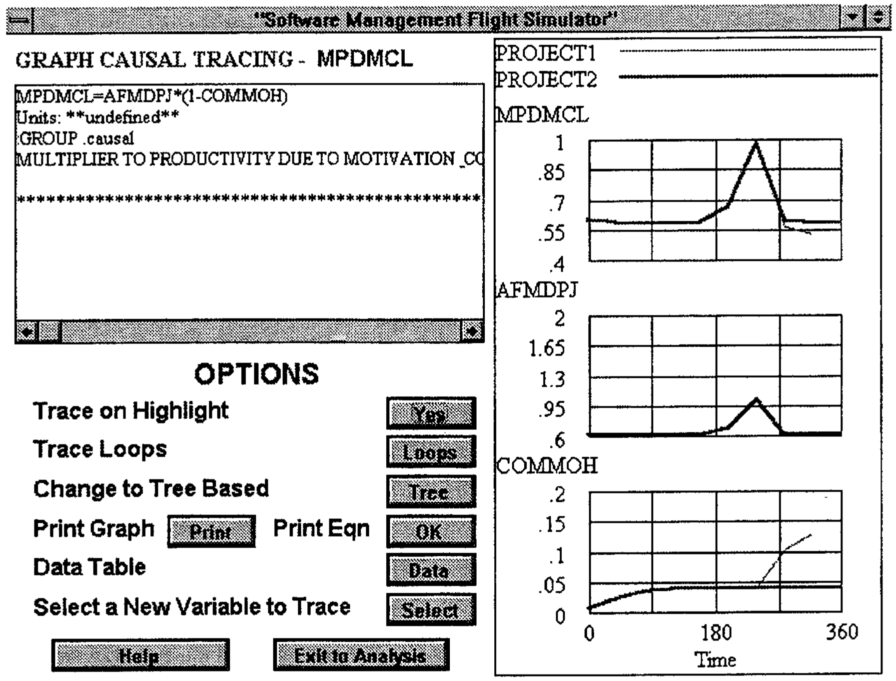

Figure 22. Multiplier due to COMMOH and Motivation Graph Causal Tracing

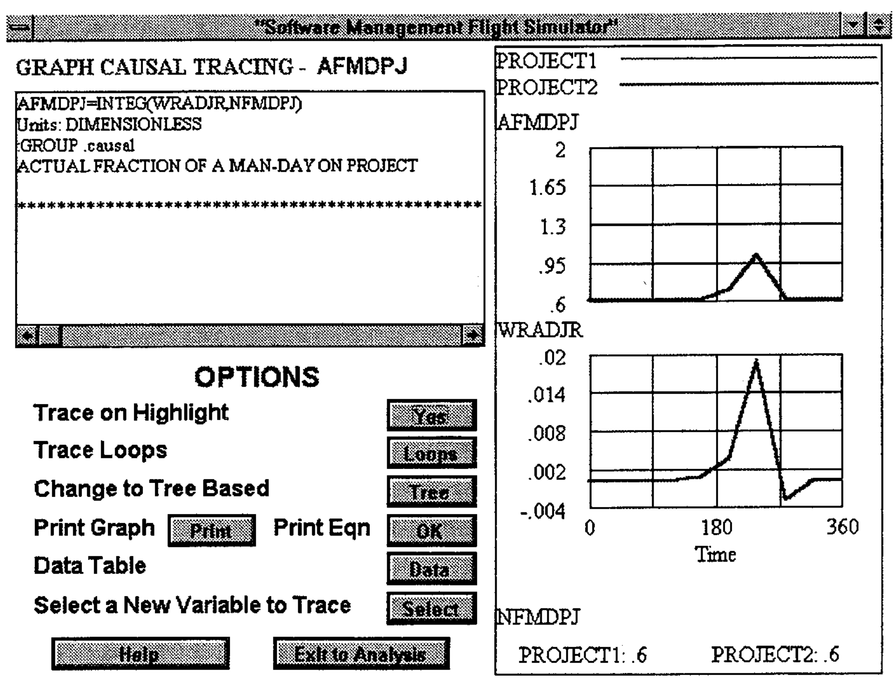

Figure 23. Actual Fraction of a Man-Day on Project Graph Causal Tracing

Further, tracing the variable **COMMOH**, shown in Figure 24, indicates that it is proportional to the total workforce level, **TOTWF**. As expected, an increase in the staff level creates a rise in **COMMOH**, as illustrated by the behavior of Project 1 in Figure 24. In turn, this increase in **COMMOH** causes **MPDMCL** to be smaller, which impacts negatively on the project's **SDVPRD**.

Continuing tracing the causes of **SDVPRD**, the **POTPRD** drops when people are added to Project 1, but starts to increase as the project approaches completion. The **POTPRD** in Project 1 is lower because hiring new inexperienced people at day 240 lowers its overall value.

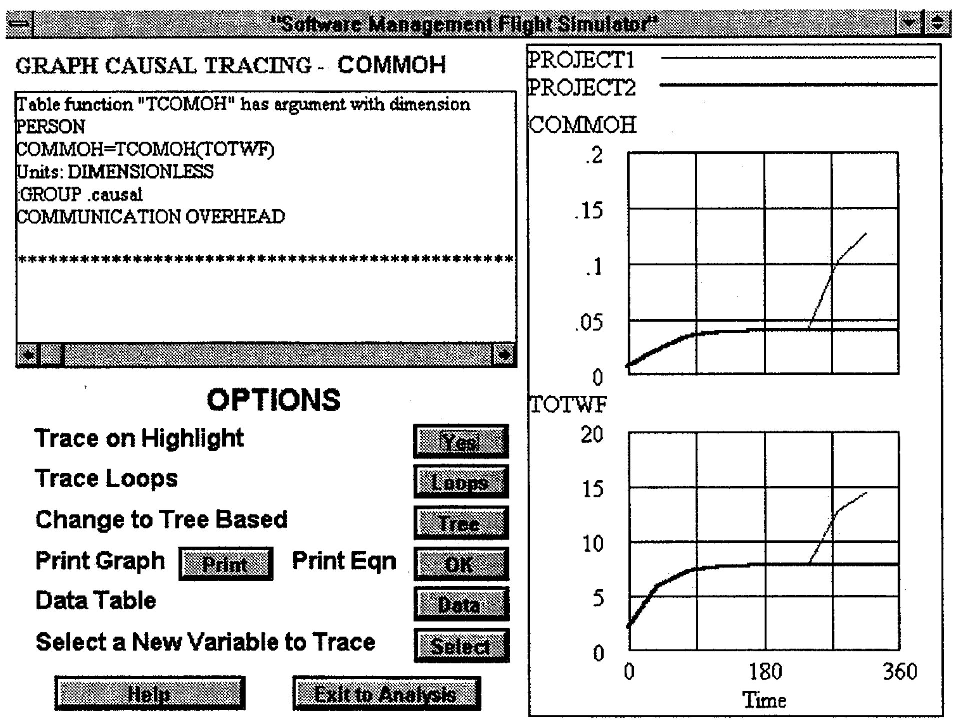

Figure 24. Communications Overhead Graph Causal Tracing

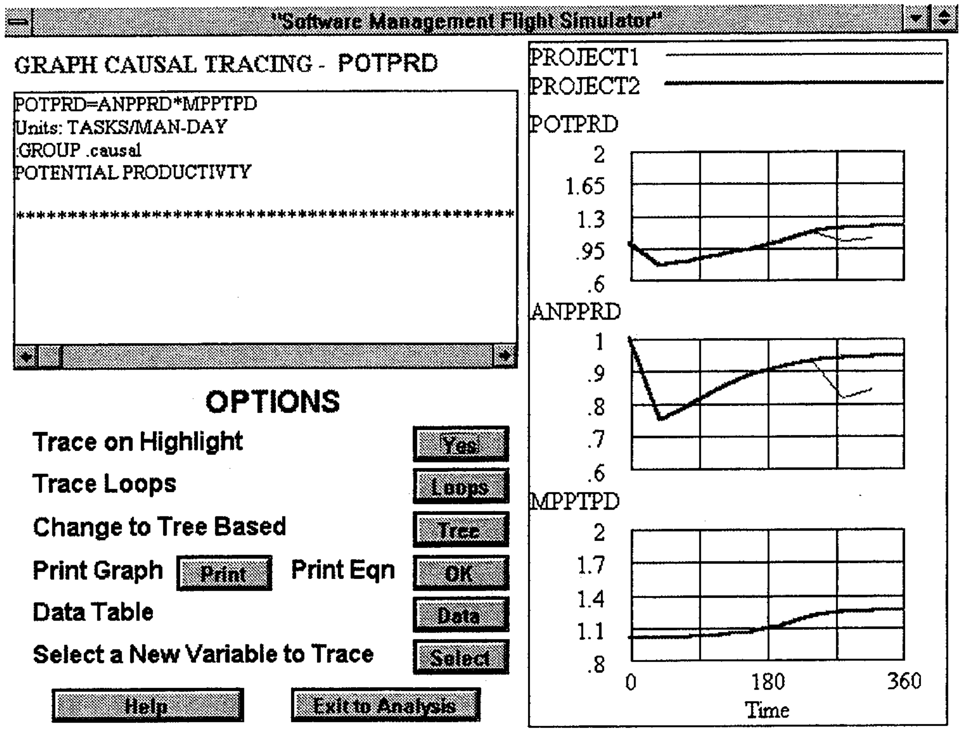

Figure 25. Potential Productivity Graph Causal Tracing

Figure 25 indicates that **POTPRD** depends on the behavior of the **ANPPRD** (Average Nominal Potential productivity) and a factor, **MPPTPD,** that accounts for learning. From the graph, Project 1 **ANPPRD** drops drastically as new people are added to the project, but starts to recover as the new staff gain in experience.

Double clicking on the variable **ANPPRD** displays its causes, as shown in Figure 26. The **FRWFEX** (Fraction of Workforce that is Experienced) is the major contributor cause for the value of the **ANPPRD**.

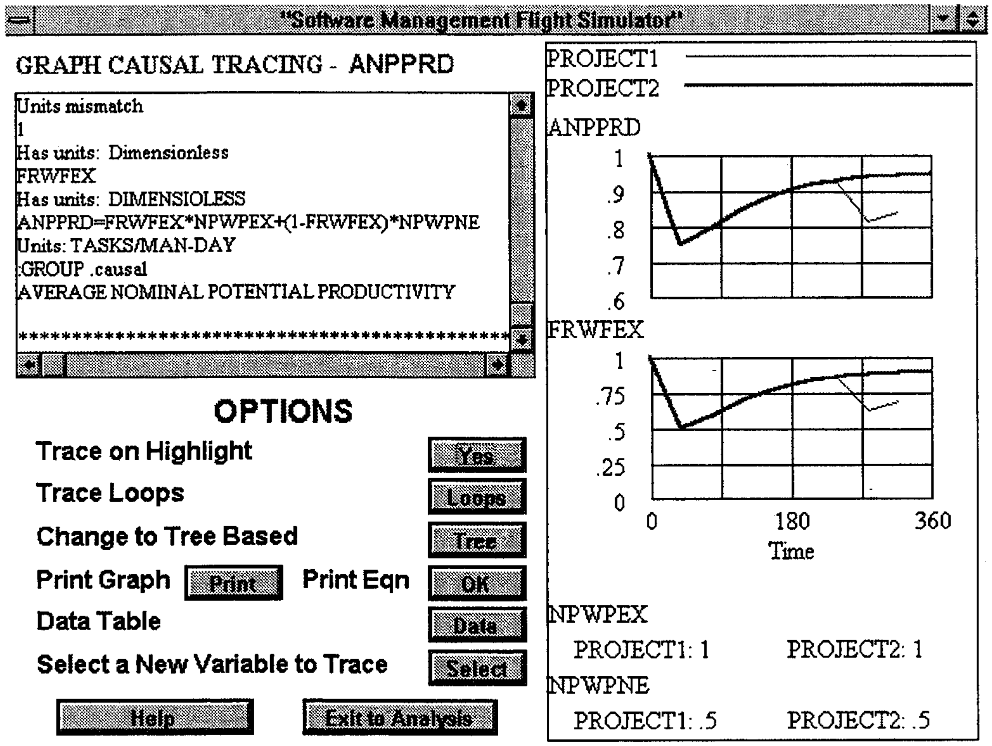

Figure 26. Average Nominal Potential Productivity Graph Causal Tracing

The SMFS' causal tracing tools assisted in revealing the following: As the total number of people increases in Project 1, the Communications Overhead associated with new people will increase. This in turn, affects the Software Development Productivity of the whole team. Similarly, as the number of people increases, the amount of experienced personnel in the project available to perform coding decreases, which in turn decreases the Potential Productivity of the group. In Project 2, the Potential Productivity is higher towards the end. The ultimate effect in Software Productivity depends on how fast the number of people is integrated and assimilated in the project.

In our scenarios, adding more people lowers the Average Nominal Productivity, which in turn, reduces the Potential Productivity of the team. This decline, when coupled with the associated communications overhead, further reduces the Software Development Productivity, which influences the Software Development Rate and Instantaneous

Productivity. However, even though the nominal software development productivity in Project 1 dropped and **COMMOH** increased as new staff was hired, the amount of productivity drop in Project 1 was not significant enough to offset the increase in staff. Since Project 1 ended before Project 2, it can be concluded that Brooks' Law does not apply in the project environment modelled here. Similar results were observed in [Abdel-Hamid, 1991].

In summary, this demonstration illustrates the utility of the SMFS Simulation Post-Analysis Screen. Similarly, a user could perform causal tracing on any variable found in the underlying model by using the analysis option available in the SMFS Control Center screen while running a simulation.

VII. CONCLUSIONS

With management's increasing reliance on mission-critical systems and the operational data they supply, information systems management faces a gigantic training and educational task. Managers need to learn how to manage in a computer-abundant world because they have the responsibility for ensuring successful delivery of the software.

Modeling and simulations play an important role in educating managers on the software project management arena. They help training students of management, as well as experienced managers on a very complex and difficult process.

Managers always have mental models, and will always modify them in the face of uncertainty. The user interface provided facilitates the process of developing, modifying and enhancing effectively the manager's mental model of the software development and project management processes that they are responsible to manage. It helps in increasing the managers current state of knowledge about how to grasp particular courses of events in software projects affected by complex, and often invisible feedback processes.

Decisions affecting complex software projects, involving highly sophisticated and technological systems, can have far-reaching consequences socially and economically. These consequences are often difficult for decision makers to predetermine. For this reason, many managers rely on their best judgment when developing plans and forecasts. Lack of experience in dealing with the complexities of software projects reveal a fundamental shortcoming. The interface provided in this thesis has been developed to help managers and students of management explore new strategies, develop new attitudes and views, and examine possible future consequences of their actions by means of causal tracing.

In a conventional classroom training, the managers are taught a wide range of material that they must remember when selecting the pertinent information to perform a particular task. This method emphasizes learning by facts. Computer-based simulation provides a training environment that differs from the traditional, lecture-based classroom environment. It forces the student to confront their weaknesses in the comprehension of

the material immediately, as opposed to merely passively receiving a lecture. The use of a flight simulator metaphor allows software project management training to be on-demand, interactive, and specific to the individual. The graphic user interface allows the manager to practice skills, and assist in developing a more complete view of their work and of reality.

VIII. ACCOMPLISHMENTS

A. USER INTERFACE

The principal focus of this thesis is to develop a graphical user interface capable of effectively implementing feedback or causal tracing, and to demonstrate its utility as a learning tool. Given the proven model for software development, the interface developed and documented in this thesis accomplishes these goals.

The interface provides a capable tool for training students and managers in making program decisions and understanding the possible unintended consequences that such decisions may have in a fictitious project's future by use of the various causal tracing mechanisms available within the SMFS Vensim based application. These mechanisms were implemented using Vensim Application (Venapps) scripting language. The equation modifications needed in the model to implement causal tracing were performed. A menu structure that provides an easy road map to information reporting and analysis was developed. A windows-based interface capable of displaying simulation results in several graphical and text formats, as well as displaying help information, was successfully created following the best guidance available for design of user interfaces.

The resulting easy-to-use interface makes the model more interactive, rather than just providing an answer requiring an interpretation by an expert. Users can either analyze their decisions while running the simulation or after the simulation has ended. Further, they can compare a number of previous simulation results to understand their different approaches, interests, and consequences. This feature provides a very powerful source for learning common, important, and often difficult real problems in software project management.

B. USER'S HANDBOOK

A user handbook was written to provide guidance on how to use the graphic user interface. Emphasis was placed on describing what the interface is capable of doing instead of the fine details of how the system operates.

IX. LESSONS LEARNED

The Vensim sketch tool allows to designer to easily create and modify the feedback structure, and the equations of a model visually. Any model imported as text can be easily depicted into a Causal Diagram, with shapes and color easily assigned to enhance its meaning. However, in the process of calling the desired variables into the sketch pad, care must be taken not to delete a variable name, if by mistake, it is selected to be shown in the sketch pad. Using the deletion tool will cause the variable to be completely eliminated from the model. Even though the environment warns you of the consequences of doing the requested action, the chance of deleting a variable by mistake is present. If you do, you will be forced to recreate the variable again - a difficult task if your model is very complex. Use the hide tool to eliminate the undesired variable instead of deleting it.

The development of the SMFS interface requires you to become very familiar with the Vensim scripting language and command syntax in other to successfully design an application. This proves to be a very challenging task. First, the Vensim documentation is very general in certain areas, and at times, very vague about most of the command syntax, and instructions provided. This makes the process of designing graphical applications a lengthy, tedious, iterative trial and error effort. The location and size of the objects, and of the screens themselves, are required to be specified in percentage of screen size, which is not conducive to rapid development of applications.

Second, to view the results of the commands used, the current version of Vensim requires the designer to launch the application to see its effects, then to exit it, if further modification to the command is needed. This makes the design of applications a time consuming process.

Third, when generating text based reports, their presentation to the screen is controlled by specifying its location in screen pixels, its width in number of characters, and its height in number of lines. This makes the generation of highly structured reports and text files a very difficult task. Also, the report appearance will vary according to computer monitor in use and the type font specified. Lastly, changes made to the .vgd

files using the Vensim workbench editing tool require that the designer exit the Vensim program and launch the Vensim program again for changes to take effect - a very cumbersome method to update text based reports.

In sum, Vensim will produce a successful interactive application, given sufficient time to build experience in using the available commands, and patience to go through the testing of the designed screens.

X. FUTURE DIRECTIONS

The interface provided in this thesis can help students enhance their understanding of the phenomena involved in a project management situation. However, future research is necessary exist in the area of interface refinement and expansion. Future interface design should implement a game "rewind" function. The new interface capability should allow the user that is running a simulation to be able to playback the current simulation to a user specified point in time, and continue the game in the desired new direction the user elects to take, without having to finish the current game, and replay all the game decisions until that point when he chooses to depart to a new direction. This additional capability will enhance the use of the SMFS by allowing the user to analyze his previous decisions, by being able to locate, through causal tracing and analysis of the reported results, a point in time where he feels a faulty policy or decision was introduced that effected the overall outcome of the simulated project, change it, and continue to replay the simulation in a completely new direction.

Refinement work is needed in terms of naming conventions and accessibility to key initial parameter settings. Current naming convention makes difficult to read and understand the names of the variables displayed in the various graphs and reports generated by the interface. The interface should have provisions to allow the instructor, or authorized user, to modify the initial default parameters setting that controls the simulation behavior. This addition would greatly increase the utility of the interface by enabling the interface to be tailored to different circumstances that could effect the project.

The creation and use of a series of simulation scenarios controlled by Vensim interfaces, in areas such as motivation, goals achievement, and risk, offer the potential opportunity for a controllable "microworld" learning environment to be available to the students. This "microworld" will enable the user to probe and experience situations that have proven to be detrimental to the profession, and impossible to experiment within the real world. Respective interface development in the areas discussed above is an area open for future work.

Use of Vensim capabilities enable the creation of a laboratory environment capable of controlled experimentation and data collection for further research in topics associated with manager's mental models and behavior interactions. The design of experiments to achieve research specific goals in these fields are areas open for future work using Vensim.

APPENDIX A.

SMFS VENSIM MODEL FILE (VMF)

This appendix provides the equation listing for the model used in the SMFS Vensim application. For the purpose of the computer simulation, this listing is identified as the file Causal.vmf. This listing follows the Vensim modeling language. This language defines a model by use of a set of equations and expressions. The language modeling structure and syntax [Ventana, 1994, p. 20] is as follows:

********************	
Causal	*Represent a Group*
********************~|	
{Comments, notes, etc.}	*Comments Syntax*
Profit =Revenue - Cost	*Represent the basic equation*
~$/yr [0,1000]	*Represent the Equation Units, Range [min, max]*
~The profit of the company	*Equation comments, can have more than one line*
:sup	*Optional Supplemental flag,*
|	*Indicates the end of the equation.*

A shorter form of an equation, were the dimensions, comments and optional flags are omitted, is as follows:

Profit = Revenues - Cost ~~|

The tilde (~) acts as separators and the bar (|) signals the end of an equation group. These delimiters are required in order to have a valid equation. Any spacing or line breaks are ignored within equations. However, line breaks are not allowed within variable names. Comments can be added anywhere in the model or equations by enclosing them in braces { }.

****

Causal

**~

VERSION 1
October 1995

****

SUMMARY OF CHANGES

****

Dynamo Changes prior to conversion to VENSIM:

1. MDSWCH=0, TOTMD1=2359.60
2. SCSWCH=0, TDEV1=296.79
3. ADDED WCWFTP, WCWFTP.K=SWITCH(HIREDY+ASIMDY,TMPRMR,TMPRMR)
4. BASE.5 / BASE MODEL: VERSION 5

VENSIM Conversion:

1. WORK FORCE SOUGHT (WFS) EQUATION WAS CHANGED TO INSERT THE CONSTANT (WFS1/ADMPPS) IN PLACE OF (WFNEED).

2. WORK FORCE AT BEGINNING OF DESIGN (WFSTRT) EQUATION WAS CHANGED TO INSERT THE CONSTANT VALUE (WFS1) IN PLACE OF INITIAL(TEAMSZ*INUDST)).

3. DAILY MANPOWER ALLOCATED FOR QA (DMPQA) EQUATION WAS CHANGED TO INSERT THE CONSTANT (FRMPQA) IN PLACE OF (AFMPQA).

4. SCHEDULED COMPLETION DATE (SCHCDT) EQUATION WAS CHANGED TO INSERT THE CONSTANT (PROJDR) IN PLACE OF (INTEG((TIME STEP*(INDCDT-SCHCDT)/SCHADT)/TIME STEP,TDEV)).

5. TOTAL JOB SIZE IN MAN DATA (JBSZMD) WAS CHANGED TO INSERT THE CONSTANT (TOTMD1) IN PLACE OF (Integ((IRDVDT+IRTSDT+ ARTJBM), DEVMD+ TSTMD)).

6. TOTMD1 EQUATION IS LISTED TWICE. REMOVED EQUATION TOTMD1= 944.

7. MISSING DYNAMO EQUATIONS WERE INSERTED INTO THE VENSIM MODEL.

8. VALUES OF (SAVEPER) AND (TIME_STEP) WERE CHANGED TO READ 40 AND 0.5 RESPECTIVELY.

9. EQUATION (IPRJSZ=(RJBDSI)*(1-UNDEST)) WAS INSERTED IN THE VENSIM MODEL.

10. VARIABLES (TOTMD1), (PROJDR), (WFS1), (FRMPQA) WERE CHANGED TO "GAME" VARIABLES.

11. ALL NON-MACRO TIME_STEP CHANGED TO TIME STEP.

12. THE FOLLOWING EQUATIONS WERE ADDED TO SUPPORT SPECIFIC GRAPHS

CUMMD TD	PROGRAMMING PERSON DAYS EXPENDED TO DATE
CMDSI KDSI	TOTAL KDSI COMPLETED
CMERD KDSI	DEFECT DENSITY
PJBSZT KDSI	ESTIMATED SYSTEM SIZE
PRQAMD	PERIOD QA PERSON DAYS PER KDSI DEVELOPED IN PERIOD
FRWFEX PCT	PERCENT OF WORKFORCE THAT IS EXPERIENCED

13. EQUATIONS ADDED TO TEST CAUSALITY

PRMD = PERSON DAYS SPENT IN PERIOD = INTEG((TOTDMP- (PRMD/
TIME STEP)*M PULSE(Time,1,TIME STEP,TIME STEP,40)),0.1)

PRDPER = PRODUCTIVITY IN 40 DAY PERIOD = PRTKDV/PRMD

INSPRD = INSTANTANEOUS PRODUCTIVITY
= (SDVRT*TIME STEP)/TOTDMP

14. ADDED WFSINI AS INITIAL GAME VALUE. THIS PREVENTS THE CONSTANT UPDATE OF INITIAL DISPLAYED VALUES IN CONTROL SCREEN.

15. CHANGED WFS1= GAME(2) TO WFS1= GAME(WFSINI) TO AVOID CONSTANT UPDATE IN CONTROL SCREEN DISPLAY.

16. ADDED TDEVINI=INTEGER(TDEV1) TO AVOID DISPLAY OF DECIMAL FRACTION IN CONTROL SCREEN DISPLAY.

17. ADDED TOTMD1INI AS INITIAL TOTAL ESTIMATED MAN DAYS. CHANGED TOTMD1INI = 2359.6 TO TOTMD1INI = 2360. THIS PREVENTS THE CONSTANT UPDATE OF INITIAL DISPLAYED VALUES IN CONTROL SCREEN.

18. CHANGED TOTMD1= GAME(2359.6) TO TOTMD1= GAME(TOTMD1INI) TO AVOID CONSTANT UPDATE IN CONTROL SCREEN DISPLAY.

19. CHANGED PROJDR=GAME(272) TO PROJDR=GAME(TDEVINI) TO MATCH THE INITIAL DURATION REPORTED INITIALLY.

{***
INITIALIZATION
****

INITIAL VALUES FOR SIMULATION

THE REAL JOB SIZE = 64,000 DSI

FROM BOEHM PAGE 90:
DISTRIBUTION OF EFFORT BY PHASE IS:
DESIGN (39%), PROGRAMMING (36%), INT TESTING (25%)

FROM BOEHM PAGE 64-65:
EFFORT = 2.4*(KDSI)**1.05 = 190 MM = 190 * 19 = 3592 MAN-DAYS

DEVELOPMENT EFFORT(@75%) = 75 %*3592 = 2695 MAN DAYS

GROSS DEV PRODUCTIVITY = 64,000/2695 = 24 DSI/MD

SCHEDULE = 2.5 * (MM)**.38 = 18 MONTHS = 348 DAYS

AVERAGE STAFF SIZE = 3592/348 = 10

GROSS PRODUCTIVITY INCORPORATES: DEV, FOR QA, & REWORKING
ASSUMING 25% OF EFFORT GOES INTO QA & REWORKING:
25% OF 2695 MAN DAYS = 674 MAN DAYS

DEVELOPMENT PRODUCTIVITY = 64,000/(2695-674) = 31 DSI/MAN-DAY

ASSUME LOSSES IN PRODUCTIVITY = 50 % THEREFORE:
POTENTIAL PRODUCTIVITY = 31 * 2 = APPROX 60 DSI/MD

DEFINE 1 TASK = 60 DSI
}

DSIPTK=60
~
~ DSI PER TASK
|

RJBDSI=64000
~
~ REAL JOB SIZE IN DSI
|

UNDEST=0.33
~ FRACTION
~ TASKS UNDERESTIMATION FRACTION
|

```
PJBDSI=INITIAL(RJBDSI*(1-UNDEST))
    ~
    ~       PERCEIVED JOB SIZE IN DSI
    |

TOTMD=INITIAL(MDSWCH*(((2.4*EXP(1.05*LN(PJBDSI/1000)))*19)*(1-UNDESM))+
    (1-MDSWCH)*TOTMD1)
    ~
    ~       TOTAL MAN DAYS
    |

UNDESM=0
    ~ FRACTION
    ~       MAN-DAYS UNDERESTIMATION FRACTION
    |

DEVMD=INITIAL(DEVPRT*TOTMD)
    ~
    ~       DEVELOPMENT MAN DAYS
    |

MDSWCH=0
    ~
    ~       SWITCH 0 OR 1
    |

TOTMD1INI=2360
    ~ MAN DAY
    ~     INITIAL ESTIMATED TOTAL MAN DAYS
    |

TOTMD1=GAME(TOTMD1INI)
    ~ MAN DAY
    ~       TOTAL MAN DAYS
    |

DEVPRT=0.8
    ~
    ~        PERCENT OF EFFORT ASSUMED NEEDED FOR DEVELOPMENT
    |

TSTMD=INITIAL((1-DEVPRT)*TOTMD)
    ~
    ~       TESTING MAN DAYS
    |
```

```
WFSTRT=WFS1
    ~ MEN
    ~       TEAM SIZE AT BEGINNING OF DESIGN
    |

INUDST=0.5
    ~ DIMENSIONLESS
    ~       INITIAL UNDERSTAFFING FACTOR
    |

TDEV=INITIAL(SCSWCH*((19*2.5*EXP(0.38*LN(TOTMD/19)))*SCHCOM)+
    (1-SCSWCH)*TDEV1)
    ~ DAYS
    ~       TOTAL DEVELOPMENT TIME
    |

SCHCOM=1
    ~ DIMENSIONLESS
    ~       SCHEDULE COMPRESSION FACTOR
    |

SCSWCH=0
    ~
    ~       SWITCH 0 OR 1
    |

TDEV1=296.79
    ~ DAYS
    ~     TIME TO DEVELOP
    |

TDEVINI=INTEGER(TDEV1)
    ~ DAYS
    ~      INITIAL TIME TO DEVELOP
    |

TEAMSZ=INITIAL((TOTMD/TDEV)/ADMPPS)
    ~ ~ |
```

```
{*******************************************************
    Control Subsystem
*******************************************************}

TIME STEP=0.5
    ~ DAYS
    ~     DT
    |

MAXLEN=1000
    ~ ~ |

SAVEPER=40
    ~ DAYS
    ~     CHANGED VALUE TO 40 DAYS VICE 10.
    |

FINAL TIME=IF THEN ELSE(PJBAWK >= 0.995,Time,MAXLEN)
    ~ ~ |

INITIAL TIME=0
    ~
    ~     ASSUMED WITH FINAL_TIME = LENGTH
    |


{*******************************************************
    Equations For Causal Tracing
*******************************************************}

PRMD=INTEG((TOTDMP-(PRMD/TIME STEP)*M PULSE(Time,1,TIME STEP,  TIME
STEP,40)),0.1)
    ~ PERSON-DAY
    ~     PERSON DAYS SPENT IN PERIOD
    |

PRDPER=PRTKDV/PRMD
    ~ DSI PER PERSON-DAY
    ~     PRODUCTIVITY IN 40 DAY PERIOD
    |
```

```
{*******************************************************
   DYNAMO Project A Peculiar Equations
*******************************************************}
WFS2=WFS1
   ~ PEOPLE
   ~     WORK FORCE SOUGHT
   |

FRMPQ1=FRMPQA
   ~ PERSONS
   ~    FRACTION OF MANPOWER FOR Q1
   |

PRDFDS=PRERD/(MAX(PRTKDV/1000,0.01))
   ~ DEFECT/KDSI
   ~    PERIOD'S DEFECT DENSITY
   |

CMDSI=CMTKDV*DSIPTK
   ~ TASKS
   ~    CUMULATIVE TASKS DEVELOPED
   |

CRDVWF=TOTDMP-DMPQA
   ~ PERSONS
   ~    CURRENT DEVELOPMENT WORK FORCE
   |

CRQAWF=(INTEGER(100*DMPQA))/100
   ~ PERSONS
   ~     CURRENT QA WORK FORCE
   |

CRRWWF=DMPRW
   ~ PEOPLE
   ~     CURRENT REWORK WORK FORCE
   |

PRCMPL=(CMDSI/PJBSZT)*100
   ~ Percent
   ~     PERCENT COMPLETE
   |

RPPROD=PRDPRD*DSIPTK
   ~ DSI/MAN-DAY
   ~     REPORTED PRODUCTIVITY
   |
```

```
FNERG=INTEG((TIME STEP*ERRGRT*IF THEN ELSE(PJBAWK >= 0.995,0,1))/TIME
STEP,0)
    ~ ERRORS
    ~     CUMULATIVE ERRORS GENERATED
    |

FNERD=INTEG((TIME STEP*ERRDRT*IF THEN ELSE(PJBAWK >= 0.995,0,1))/TIME
STEP,0)
    ~ ERRORS
    ~     CUMULATIVE ERRORS DETECTED
    |

FNERES=FNERG-FNERD
    ~ ERRORS
    ~     ERRORS THAT ESCAPED QA
    |

FNPRDT=100*FNERD/MAX(1,FNERG)
    ~ Percent
    ~     PERCENT DETECTED
    |

FNQAMD=INTEG((TIME STEP*DMPQA*IF THEN ELSE(PJBAWK >= 0.995,0,1))/
    TIME STEP,0)
    ~ MAN-DAYS
    ~     CUMULATIVE QA MAN-DAYS
    |

FNTRMD=INTEG((TIME STEP*DMPTRN*IF THEN ELSE(PJBAWK >= 0.995,0,1))/ TIME
STEP,0)
    ~
    ~     CUMULATIVE TRAINING MAN-DAYS
    |

FNRWMD=INTEG((TIME STEP*DMPRW*IF THEN ELSE(PJBAWK >= 0.995,0,1))/TIME
STEP,0)
    ~ MAN-DAYS
    ~     CUMULATIVE REWORK MAN-DAYS
    |

TM=Time
    ~ ~ |

PJBSZT=PJBSZ*DSIPTK
    ~ DSI
    ~     PERCEIVED JOB SIZE IN LINES OF CODEPERCEIVED JOB SIZE IN DSI
    |
```

```
IPRJSZ=INITIAL((RJBDSI)*(1-UNDEST))
    ~ DSI
    ~     INITIAL PROJECT SIZE IN DSI
    |

FNCOST=INTEG((TIME STEP*TOTDMP*IF THEN ELSE(PJBAWK >= 0.995,0,1))/TIME
STEP,0)
    ~ MAN-DAYS
    ~     FINAL COST IN MAN-DAYS
    |

FNTIME=INTEG(IF THEN ELSE(PJBAWK >= 0.995,0,1),0)
    ~ ~ |

FNERR=INTEG(((IF THEN ELSE(PJBAWK >= 0.995,FNERR,ALESER)/TIME STEP)-
    FNERR/TIME STEP),0)
    ~ ~ |

PJBSZT KDSI=PJBSZT/1000
    ~ DSI
    ~     ESTIMATED SYSTEM SIZE (KDSI)
    |

PRQAMD PERIOD=PRQAMD/((PRTKDV+0.01)/1000)
    ~ PERSON DAYS
    ~     QA PERSON DAYS PER KDSI DEVELOPED IN PERIOD
    |

CUMMD TD=CUMMD-CMQAMD
    ~ PERSON DAYS
    ~     PROGRAMMING PERSON DAYS EXPENDED TO DATE
    |

CMDSI KDSI=CMDSI/1000
    ~ TASKS
    ~     TOTAL KDSI COMPLETED
    |

CMERD KDSI=CMERD*(1000/(CMDSI+0.01))
    ~ DEFECTS/KDSI
    ~     DEFECT DENSITY PER KDSI
    |

FRWFEX PCT=FRWFEX*100
    ~ DIMENSIOLESS
    ~     FRACTION OF WF THAT IS EXPERIENCED
    |
```

```
{*************************************************
 VENSIM MACRO FOR DYNAMO FUNCTION
**************************************************
 This macro definition is for the PULSE function commonly used in DYNAMO,
 but not directly supported in Vensim.

NOTE:   M__PULSE is equivalent to the DYNAMO function PULSE
         M_PULSE takes Time as an argument
         SAMPLE takes Time and TIME STEP as arguments}
:MACRO: M PULSE(time,height,width,first,intvl)

M PULSE = height* PULSE(pulse_start,width)
    ~ height
    ~     Note that the pulse function in Vensim is different from the pulsefunction in
DYNAMO.  The argument time needs to be added to get repeated pulses - things may
still be misaligned.
    |

pulse_start = IF THEN ELSE(time < first+intvl,first,first + (QUANTUM((time-
     first)/intvl,1))*intvl)
    ~ time
    ~     The pulse start moves forward over time.  It makes no sense to have width > interval,
       and interval = 0 will cause an error.
    |

:END OF MACRO:

:MACRO: SAMPLE(Time,TIME STEP,INITIAL TIME,X,INTVL,ISAM)

SAMPLE=SAMPLE IF TRUE(Time > next_time,X,X)
    ~ ~ |

next_time=INTEG(IF THEN ELSE(Time>next_time,INTVL/TIME STEP,0),
     INITIAL TIME-TIME STEP/2)
    ~ Time
    ~
    |

:END OF MACRO:

PRQAMD=INTEG((DMPQA-(PRQAMD/TIME STEP)*M PULSE(Time,1,TIME STEP, TIME
     STEP,40)),0)
    ~ PERSON-DAYS
    ~     QA PERSON-DAYS IN PERIOD
    |
```

```
PRERD=INTEG((ERRDRT-(PRERD/TIME STEP)*M PULSE(Time,1,TIME STEP, TIME
    STEP,40)),0)
    ~ ERRORS
    ~    DETECTED ERRORS DURING PERIOD
    |

TMSTOP=IF THEN ELSE(PJBAWK*M PULSE(Time,1,TIME STEP,TIME STEP,40) >=
    0.995,Time,MAXLEN)
    ~
    ~    FINAL TIME
    |

PRTKDV=INTEG((SDVRT*DSIPTK-(PRTKDV/TIME STEP)*M PULSE(Time,1,TIME
STEP,TIME     STEP,40)),0.1)
    ~
    ~    TASKS DEVELOPED DURING 40 DAY PERIOD
    |
```

```
{*****************************************************
   Human Resource Management Subsystem
*****************************************************}

WFNEW=INTEG((HIRERT-ASIMRT-NEWTRR),0)
   ~ PEOPLE
   ~     NEW WORKFORCE
   |

HIRERT=MAX(0,WFGAP/HIREDY)
   ~ PEOPLE/DAY
   ~     HIRING RATE
   |

HIREDY=40
   ~ DAYS
   ~     HIRING DELAY
   |

WFGAP=WFS-TOTWF
   ~ PEOPLE
   ~     WORKFORCE GAP
   |

NEWTRR=MIN(TRNFRT,WFNEW/TIME STEP)
   ~ PEOPLE/DAY
   ~     NEW EMPLOYEES TRANSFER RATE OUT
   |

TRNFRT=MAX(0,-WFGAP/TRNSDY)
   ~ PEOPLE/DAY
   ~     TRANSFER RATE OF PEOPLE OUT OF PROJECT
   |

TRNSDY=10
   ~ DAYS
   ~     TIME DELAY TO TRANSFER PEOPLE OUT
   |

ASIMRT=WFNEW/ASIMDY
   ~ PEOPLE/DAY
   ~     ASSIMILATION RATE OF NEW EMPLOYEES
   |

ASIMDY=80
   ~ DAYS
   ~     AVERAGE ASSIMILATION DELAY
   |
```

DMPTRN=WFNEW*TRPNHR
~ MAN DAYS/DAY
~ DAILY MANPOWER FOR TRAINING
|

TRPNHR=0.2
~ DIMENSIONLESS
~ NUMBER OF TRAINERS PER NEW EMPLOYEE
|

CMTRMD=INTEG(DMPTRN,0)
~
~ CUMULATIVE TRAINING MAN-DAYS
|

WFEXP=INTEG((ASIMRT-EXPTRR-QUITRT),WFSTRT)
~ PEOPLE
~ EXPERIENCED WORKFORCE INITIAL VALUE OF EXPERIENCED WORKFORCE LEVEL
|

EXPTRR=MIN(WFEXP/TIME STEP,TRNFRT-NEWTRR)
~ PEOPLE/DAY
~ EXPERIENCED EMPLOYEES TRANSFER RATE
|

QUITRT=WFEXP/AVEMPT
~ PEOPLE/DAY
~ EXPERIENCED EMPLOYEES QUIT RATE
|

AVEMPT=673
~ DAYS
~ AVERAGE EMPLOYMENT TIME
|

FTEXWF=WFEXP*ADMPPS
~ MEN
~ FULL-TIME-EQUIVALENT EXPERIENCED WF
|

CELNWH=FTEXWF*MNHPXS
~ MEN
~ CEILING ON NEW HIREES
|

```
MNHPXS=3
    ~ MEN/MEN
    ~       MOST NEW HIREES PER EXPERIENCED STAFF
    |

CELTWF=CELNWH+WFEXP
    ~ PEOPLE
    ~       CEILING ON TOTAL WORKFORCE
    |

WFS=MIN(CELTWF,WFS1/ADMPPS)
    ~ PEOPLE
    ~       WF SOUGHT
    |

WFSINI=2
    ~ PEOPLE
    ~     INITIAL VALUE OF STAFFING LEVEL
    |

WFS1=GAME(WFSINI)
    ~ PEOPLE
    ~       TOTAL REQUESTED STAFFING LEVEL
    |

TOTWF=WFNEW+WFEXP
    ~ PEOPLE
    ~       TOTAL WF LEVEL
    |

FTEQWF=TOTWF*ADMPPS
    ~ PERSONS
    ~      FULL TIME EQUIVALENT WF
    |

FRWFEX=(INTEGER((WFEXP/TOTWF)*10000))/10000
    ~ DIMENSIOLESS
    ~        FRACTION OF WF THAT IS EXPERIENCED
    |
```

{***
Software Production Subsystem
***}

{(A) MANPOWER ALLOCATION SECTOR}

TOTDMP=TOTWF*ADMPPS
~ MAN-DAYS/DAY
~ TOTAL DAILY MANPOWER
|

ADMPPS=1
~ DAY/DAY
~ AVERAGE DAILY MANPOWER PER STAFF
|

CUMMD=INTEG(TOTDMP,0.0001)
~ MAN DAYS
~ CUMULATIVE MAN-DAYS EXPENDED
|

DMPATR=TOTDMP-DMPTRN
~ MAN-DAYS/DAY
~ DAILY MANPOWER AVAILABLE AFTER TRAINING
|

AFMPQA=ACTIVE INITIAL(PFMPQA*(1+ADJQA),PFMPQA)
~ DIMENSIONLESS
~ ACTUAL FRACTION OF MANPOWER FOR QA
|

QO=0
~
~ QUALITY OBJECTIVE ... NORMAL QO = 0
|

PFMPQA=TPFMQA(PJBAWK)*(1+QO/100)
~ DIMENSIONLESS
~ PLANNED FRACTION OF MANPOWER FOR QA
|

TPFMQA(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,0.15,0.15,0.15,0.15,0.15,0.15,0.15,0.15,0.15,
0.15,0)
~ ~ |

ADJQA=TADJQA(SCHPR)
~ Percent
~ Percent ADJUSTMENT IN PFMPQA
|

```
TADJQA(0,0.1,0.2,0.3,0.4,0.5,0,-0.025,-0.15,-0.35,-0.475,-0.5)
    ~ ~ |

DMPQA=MIN(((FRMPQA/100)*TOTDMP),0.9*DMPATR)
    ~ MAN-DAYS/DAY
    ~      DAILY MANPOWER ALLOCATED FOR QA
    |

FRMPQA=GAME(10)
    ~ PERSONS
    ~      FRACTION OF MANPOWER ALLOCATED FOR QA
    |

CMQAMD=INTEG(DMPQA,0)
    ~ MAN-DAYS
    ~      CUMULATIVE QA MAN-DAYS
    |

DMPSWP=DMPATR-DMPQA
    ~ MAN-DAYS/DAY
    ~      DAILY MANPOWER FOR SOFTWARE PRODUCTION
    |

DESECR=ACTIVE INITIAL(DTCERR/DESRWD,0)
    ~ ERRORS/DAY
    ~      DESIRED ERROR CORRECTION RATE
    |

DESRWD=15
    ~ DAYS
    ~      DESIRED REWORK DELAY
    |

DMPRW=ACTIVE INITIAL(MIN((DESECR*PRWMPE),DMPSWP),0)
    ~ MAN-DAYS/DAY
    ~      DAILY MANPOWER ALLOCATED FOR REWORK
    |

PRWMPE=INTEG((RWMPPE-PRWMPE)/TARMPE,0.5)
    ~ MAN-DAYS/ERROR
    ~      PERCEIVED REWORK MANPOWER NEEDED PER ERROR
    |

TARMPE=10
    ~ DAYS
    ~      TIME TO ADJUST PRWMPE
    |
```

```
CMRWMD=INTEG(DMPRW,0)
    ~ MAN DAYS
    ~      CUMULATIVE REWORK MAN-DAYS
    |

DMPDVT=DMPSWP-DMPRW
    ~ MAN-DAYS/DAYS
    ~      DAILY MANPOWER FOR DEVELOPMENT/ TESTING
    |

CMDVMD=INTEG((TIME STEP*DMPDVT*(1-FREFTS))/TIME STEP,0)
    ~ MAN DAYS
    ~      CUMULATVE DEVELOPMENT MAN-DAYS
    |
```

{(B) SOFTWARE DEVELOPMENT SECTOR}

```
SDVRT=ACTIVE INITIAL(MIN((DMPSDV*SDVPRD),TSKPRM/TIME STEP),0)
    ~ TASKS/DAY
    ~      SOFTWARE DEVELOPMENT RATE
    |

DMPSDV=DMPDVT*(1-FREFTS)
    ~ MAN-DAYS/DAY
    ~      DAILY MANPOWER FOR SOFTWARE DEVELOPMENT
    |

INSPRD=(SDVRT*TIME STEP)/TOTDMP
    ~
    ~      INSTANTANEOUS PRODUCTIVITY
    |

FREFTS=TFEFTS(TSKPRM/PJBSZ)
    ~ DIMENSIONLESS
    ~      FRACTION OF EFFORT FOR SYSTEM TESTING
    |

TFEFTS(0,0.04,0.08,0.12,0.16,0.2,1,0.5,0.28,0.15,0.05,0)
    ~ ~ |

SDVPRD=POTPRD*MPDMCL
    ~ TASKS/MAN-DAY
    ~      SOFTWARE DEVELOPMENT PRODUCTIVITY
    |

POTPRD=ANPPRD*MPPTPD
    ~ TASKS/MAN-DAY
    ~      POTENTIAL PRODUCTIVTY
    |
```

```
ANPPRD=FRWFEX*NPWPEX+(1-FRWFEX)*NPWPNE
    ~ TASKS/MAN-DAY
    ~      AVERAGE NOMINAL POTENTIAL PRODUCTIVITY
    |

NPWPEX=1
    ~ TSK/M-D
    ~      NOMINAL POTENTIAL PRODUCTIVITY OF EXP EMPLOYEE
    |

NPWPNE=0.5
    ~ TSK/M-D
    ~      NOMINAL POTENTIAL PROD OF NEW EMPL.
    |

MPPTPD=TMPTPD(PJBAWK)
    ~ DIMENSIONLESS
    ~      MULTIPLIER TO POTENTIAL PRODUCTIVITY DUE TO LEARNING
    |

TMPTPD(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,1,1.0125,1.0325,1.055,1.09,1.15,1.2,1.22,
        1.245,1.25,1.25)
    ~ ~ |

MPDMCL=AFMDPJ*(1-COMMOH)
    ~ DIMENSIONLESS
    ~      MULTIPLIER TO PRODUCTIVITY DUE TO MOTIVATION & COMM LOSSES
    |

COMMOH=TCOMOH(TOTWF)
    ~ DIMENSIONLESS
    ~      COMMUNICATION OVERHEAD
    |

TCOMOH(0,5,10,15,20,25,30,0,0.015,0.06,0.135,0.24,0.375,0.54)
    ~ ~ |

NFMDPJ=0.6
    ~ DIMENSIONLESS
    ~      NOMINAL FRACTION OF A MAN-DAY ON PROJECT
    |

AFMDPJ=INTEG(WRADJR,NFMDPJ)
    ~ DIMENSIONLESS
    ~      ACTUAL FRACTION OF A MAN-DAY ON PROJECT
    |
```

```
WRADJR=(WKRTS-AFMDPJ)/WKRADY
    ~ 1/DAY
    ~      WORK RATE ADJUSTMENT RATE
    |

WKRADY=NWRADY*EWKRTS
    ~ DAYS
    ~      WORK RATE ADJUSTMENT DELAY
    |

NWRADY=TNWRAD(TIMERM)
    ~ DAYS
    ~      NORMAL WORK RATE ADJUSTMENT DELAY
    |

TNWRAD(0,5,10,15,20,25,30,2,3.5,5,6.5,8,9.5,10)
    ~ ~ |

EWKRTS=IF THEN ELSE(WKRTS >= AFMDPJ,1,0.75)
    ~ DIMENSIONLESS
    ~      EFFECT OF WORK RATE SOUGHT
    |

WKRTS=(1+PBWKRS)*NFMDPJ
    ~ DIMENSIONLESS
    ~      WORK RATE SOUGHT
    |

MAXMHR=INITIAL(1)
    ~ DIMENSIONLESS
    ~      MAXIMUM BOOST IN MAN-HOURS
    |

PBWKRS=IF THEN ELSE(PMDSHR >= 0,(MDHDL/(FTEQWF*(OVWDTH+0.0001))),
    (MDHDL/(TMDPSN-MDHDL+0.0001)))
    ~ Percent
    ~      Percent BOOST IN WORK RATE SOUGHT
    |

MDHDL=IF THEN ELSE(PMDSHR >= 0,MIN(MAXSHR,PMDSHR),-EXSABS)*CTRLSW
    ~ MAN-DAYS
    ~      MAN-DAYS THAT WILL BE HANDLED OR ABSORBED
    |

CTRLSW=1
    ~ Zero or One
    ~      CONTROL SWITCH ... ALLOWS US TO TEST POLICY OF NO OVERWORK
    |
```

```
EXSABS=MAX(0,(TEXABS(TMDPSN/MDRM)*MDRM-TMDPSN))
    ~ MAN-DAYS
    ~       MAN-DAY EXCESSES THAT WILL BE ABSOBED
    |

TEXABS(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,0,0.2,0.4,0.55,0.7,0.8,0.9,0.95,1,1,1)
    ~ ~ |

MAXSHR=(OVWDTH*FTEQWF*MAXMHR)*WTOVWK
    ~ MAN-DAYS
    ~       MAXIMUM SHORTAGE IN MAN-DAYS THAT CAN BE HANDLED
    |

WTOVWK=IF THEN ELSE(Time >= BRKDTM+RLXTMC,1,0)
    ~ Zero or One
    ~       WILLINGNESS TO OVERWORK
    |

BRKDTM=INTEG((TIME STEP*(1/TIME STEP)*(MAX(BRKDTM,IF THEN ELSE
    (OVWDTH = 0,(Time+TIME STEP),0))-BRKDTM))/TIME STEP,-1)
    ~
    ~       TIME OF LAST EXHAUSTION BREAKDOWN
    |

RLXTMC=INTEG((IF THEN ELSE(EXHLEV/MXEXHT >= 0.1,1,-RLXTMC/TIME    STEP)-
((1/TIME STEP)*RLXTMC*IF THEN ELSE(OVWDTH = 0,1,0))),0)
    ~
    ~       VARIABLE THAT CONTROLS TIME TO DE-EXHAUST
    |

OVWDTH=NOVWDT*MODTEX
    ~ DAYS
    ~       OVERWORK DURATION THRESHOLD
    |

NOVWDT=TNOWDT(TIMERM)
    ~ DAYS
    ~       NOMINAL OVERWORK DURATION THRESHOLD
    |

TNOWDT(0,10,20,30,40,50,0,10,20,30,40,50)
    ~ ~ |

MODTEX=TMODEX(EXHLEV/MXEXHT)
    ~ DIMENSIONLESS
    ~       EFFECT OF EXHAUSTION ON OVERWORK DURATION THRESHOLD
    |
```

```
TMODEX(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,1,0.9,0.8,0.7,0.6,0.5,0.4,0.3,0.2,0.1,0)
    ~ ~ |

EXHLEV=INTEG((RIEXHL-RDEXHL),0)
    ~ EXHAUST UNITS
    ~      EXHAUSTION LEVEL
    |

RIEXHL=TRIXHL((1-AFMDPJ)/(1-NFMDPJ))
    ~ EXHAUST UNITS/DAY
    ~      RATE OF INCREASE IN EXHAUSTION LEVEL
    |

TRIXHL(-0.5,-0.4,-0.3,-0.2,-0.1,7.45058e-009,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,2.5,
    2.2,1.9,1.6,1.3,1.15,0.9,0.8,0.7,0.6,0.5,0.4,0.3,0.2,0,0)
    ~ ~ |

RDEXHL=IF THEN ELSE(0 >= RIEXHL,EXHLEV/EXHDDY,0)
    ~ EXHAUST UNITS/DAY
    ~      RATE OF DEPLETION IN EXHAUSTION LEVEL
    |

EXHDDY=20
    ~ DAYS
    ~      EXHAUSTION DEPLETION DELAY TIME
    |

MXEXHT=50
    ~ EXHAUST UNITS
    ~      MAXIMUM TOLERABLE EXHAUSTION
    |
```

{(C) QUALITY ASSURANCE AND REWORK SECTOR}

```
QART=DELAY3(SDVRT,AQADLY)
    ~ TASKS/DAY
    ~      FOR QA RATE
    |

TSKWK=INTEG((SDVRT-QART),0)
    ~ TASKS
    ~      TASKS WORKED
    |

AQADLY=10
    ~ DAYS
    ~      AVERAGE DELAY FOR QA     |
```

```
CUMTQA=INTEG((QART-TSRATE),0)
    ~ TASKS
    ~      CUMULATIVE TASKS QA'ED
    |

ANERPT=MAX(PTDTER/(TSKWK+0.0001),0)
    ~ ERRORS/TASK
    ~      AVERAGE # OF ERRORS PER TASK
    |

QAMPNE=NQAMPE*(1/MPDMCL)*MDEFED
    ~ MAN-DAYS/ERROR
    ~      QA MANPOWER NEEDED TO DETECT AVERAGE ERROR
    |

NQAMPE=TNQAPE(PJBAWK)
    ~ MAN-DAYS/ERROR
    ~      NOMINAL QA MANPOWER NEEDED TO DETECT AVERAGE ERROR    |

TNQAPE(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,0.4,0.4,0.39,0.375,0.35,0.3,0.25,0.225,0.21,
    0.2,0.2)
    ~ ~ |

MDEFED=TMDFED(ERRDSY)
    ~ DIMENSIONLESS
    ~      MULTIPLIER TO DETECTION EFFORT DUE TO ERROR DENSITY
    |

TMDFED(0,1,2,3,4,5,6,7,8,9,10,50,36,26,17.5,10,4,1.75,1.2,1,1,1) ~ ~ |
ERRDSY=ANERPT*1000/DSIPTK
    ~ ERRORS/KDSI
    ~      ERROR DENSITY
    |

PERDRT=DMPQA/QAMPNE
    ~ ERRORS/DAY
    ~      POTENTIAL ERROR DETECTION RATE
    |

ERRDRT=MIN(PERDRT,PTDTER/TIME STEP)
    ~ ERRORS/DAY
    ~      ERROR DETECTION RATE
    |

CMERD=INTEG(ERRDRT,0)
    ~ ERRORS
    ~      CUMULATIVE ERRORS DETECTED
    |
```

PRCTDT=100*CMERD/(CUMERG+0.001)
~ Percent
~ PERCENT ERRORS DETECTED
|

ERRSRT=QART*ANERPT
~ ERRORS/DAY
~ ERROR ESCAPE RATE
|

CMERES=INTEG(ERRSRT,0)
~ ERRORS
~ CUMULATIVE ERRORS THAT ESCAPED
|

PTDTER=INTEG((ERRGRT-ERRDRT-ERRSRT),0)
~ ERRORS
~ POTENTIALLY DETECTABLE ERRORS
|

ERRGRT=SDVRT*ERRPTK
~ ERRORS/DAY
~ ERROR GENERATION RATE
|

ERRPTK=NERPTK*MERGSP*MERGWM
~ ERRORS/TASK
~ ERRORS PER TASK
|

NERPTK=NERPK*DSIPTK/1000
~ ERRORS/TASK
~ NOMINAL # OF ERRORS COMMITTED PER TASK
|

NERPK=TNERPK(PJBAWK)
~ ERRORS/KDSI
~ NOMINAL # OF ERRORS COMMITTED PER KDSI
|

TNERPK(0,0.2,0.4,0.6,0.8,1,25,23.86,21.59,15.9,13.6,12.5)
~ ~ |

MERGSP=TMEGSP(SCHPR)
~ DIMENSIONLESS
~ MULTIPLIER TO ERROR GENERATION DUE TO SCHEDULE PRESSURE
|

TMEGSP(-0.4,-0.2,0,0.2,0.4,0.6,0.8,1,0.9,0.94,1,1.05,1.14,1.24,1.36,1.5)
~ ~ |

MERGWM=TMEGWM(FRWFEX)
~ DIMENSIONLESS
~ MULTIPLIER TO ERROR GENERATION DUE TO WORKFORCE MIX
|

TMEGWM(0,0.2,0.4,0.6,0.8,1,2,1.8,1.6,1.4,1.2,1)
~ ~ |

CUMERG=INTEG(ERRGRT,0)
~ ERRORS
~ CUMULATIVE ERRORS GENERATED DIRECTLY DURING WORKING
|

DTCERR=INTEG((ERRDRT-RWRATE),0)
~ ERRORS
~ DETECTED ERRORS
|

RWRATE=DMPRW/RWMPPE
~ ERRORS/DAY
~ REWORK RATE
|

RWMPPE=NRWMPE/MPDMCL
~ MAN-DAYS/ERROR
~ REWORK MANPOWER NEEDED PER ERROR
|

NRWMPE=TNRWME(PJBAWK)
~ MAN-DAYS/ERROR
~ NOMINAL REWORK MANPOWER NEEDED PER ERROR
|

TNRWME(0,0.2,0.4,0.6,0.8,1,0.6,0.575,0.5,0.4,0.325,0.3)
~ ~ |

CMRWED=INTEG(RWRATE,0)
~ ERRORS
~ CUMULATIVE REWORKED ERRORS DURING DEVELOPMENT
|

{(D) SYSTEM TESTING SECTOR}

UDAVER=INTEG((AEGRT+AERGRT-AERRRT-DCRTAE),0)
~ ERRORS
~ UNDETECTED ACTIVE ERRORS |

AEGRT=(ERRSRT+BDFXGR)*FRAERR
~ ERRORS/DAY
~ ACIVE ERRORS GENERATION RATE
|

BDFXGR=RWRATE*PBADFX
~ ERRORS/DAY
~ BAD FIXES GENERATE RATE
|

PBADFX=0.075
~ FRACTION
~ PERCENT BAD FIXES
|

FRAERR=TFRAER(PJBAWK)
~ DIMENSIONLESS
~ FRACTION OF ESCAPING ERRORS THAT WILL BE ACTIVE
|

TFRAER(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,1,1,1,1,0.95,0.85,0.5,0.2,0.075,0,0)
~ ~ |

AERGRT=SDVRT*SMOOTH(AERRDS,TSAEDS)*MAERED
~ ERRORS/DAY
~ ACTIVE ERRORS REGENERATION RATE |

MAERED=TMERED(SMOOTH(AERRDS*1000/DSIPTK,TSAEDS))
~ DIMENSIONLESS
~ MULTIPLIER TO ACTIVE ERROR REGENERATION DUE TO ERROR DENSITY
|

TMERED(0,10,20,30,40,50,60,70,80,90,100,1,1.1,1.2,1.325,1.45,1.6,2,2.5,3.25,4.35,6)
~ ~ |

TSAEDS=40
~ DAYS
~ TIME TO SMOOTH ACTIVE ERROR DENSITY (AERRDS)
|

AERRDS=UDAVER/(CUMTQA+0.1)
~ ERRORS/TASK
~ ACTIVE ERROR DENSITY
|

AERRRT=UDAVER*AERRFR
~ ERRORS/DAY
~ ACTIVE ERRORS RETIRING RATE
|

AERRFR=TERMFR(PJBAWK)
~ 1/DAYS
~ ACTIVE ERRORS RETIRING FRACTION
|

TERMFR(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,0,0,0,0,0.01,0.02,0.03,0.04,0.1,0.3,1)
~ ~ |

DCRTAE=MIN(TSRATE*AERRDS,UDAVER/TIME STEP)
~ ERRORS/DAY
~ DETECTION/CORRECTION RATE OF ACTIVE ERRORS
|

UDPVER=INTEG((PEGRT+AERRRT-DCRTPE),0)
~ ERRORS
~ UNDETECTED PASSIVE ERRORS
|

PEGRT=(ERRSRT+BDFXGR)*(1-FRAERR)
~ ERRORS/DAY
~ PASSIVE ERRORS GENERATION RATE
|

DCRTPE=MIN(TSRATE*PERRDS,UDPVER/TIME STEP)
~ ERRORS/DAY
~ DETECT/CORRECT RATE OF PASSIVE ERRORS
|

CMRWET=INTEG((DCRTPE+DCRTAE),0)
~ ERRORS
~ CUMULATIVE ERRORS REWORKED IN TESTING PHASE
|

ALESER=UDAVER+UDPVER+CMRWET
~ ERRORS
~ ALL ERRORS THAT ESCAPED AND WERE GENERATED
|

DMPTST=DMPDVT*FREFTS
~ MAN DAYS/DAY
~ DAILY MANPOWER FOR TESTING
|

```
CMTSMD=INTEG(DMPTST,0)
    ~ MAN DAYS
    ~       CUMULATIVE TESTING MAN-DAYS
    |

TSRATE=MIN(CUMTQA/TIME STEP,DMPTST/TMPNPT)
    ~ TASKS/DAY
    ~       TESTING RATE
    |

TMPNPT=(TSTOVH*(DSIPTK/1000)+TMPNPE*(PERRDS+AERRDS))/MPDMCL
    ~ MAN-DAYS/TASK
    ~       TESTING MANPOWER NEEDED PER TASK
    |

TSTOVH=1
    ~ MAN-DAYS/KDSI
    ~       TESTING EFFORT OVERHEAD
    |

TMPNPE=0.15
    ~ MAN-DAY/ERROR
    ~       TESTING MANPOWER NEEDED PER ERROR
    |

PTKTST=CUMTKT/PJBSZ
    ~ PERCENT
    ~       PERCENT OF TASKS TESTED
    |

PERRDS=UDPVER/(CUMTQA+0.0001)
    ~ ERRORS/TASK
    ~       PASSIVE ERROR DENSITY
    |

CUMTKT=INTEG(TSRATE,0)
    ~ TASKS
    ~       CUMULATIVE TASKS TESTED
    |

ALLERR=PTDTER+DTCERR+CMRWED+UDAVER+UDPVER+CMRWET
    ~ ERRORS
    ~       ALL ERRORS    |
ALLRWK=CMRWED+CMRWET
    ~ ERRORS
    ~       ALL ERRORS REWORKED ... IN DEVELOPMENT AND TESTING
    |
```

```
CMTKDV=INTEG(SDVRT,0)
    ~ TASKS
    ~       CUMULATIVE TASKS DEVELOPED
    |

PJBAWK=CMTKDV/RJBSZ
    ~ PERCENT
    ~       PERCENT OF JOB ACTUALLY WORKED
    |

PJDPRD=TSKPRM/(MDPRNT+0.1)
    ~ TASKS/MAN-DAY
    ~       PROJECTED DEVELOPMENT PRODUCTIVITY
    |

MDPRNT=MAX(0,MDRM-MDPNRW-MDPNTS)
    ~ MAN-DAYS
    ~       MAN DAYS PERCEIVED REMAINING FOR NEW TASKS
    |

MDPNRW=DTCERR*PRWMPE
    ~
    ~       MAN DAYS PERCEIVED NEEDED FOR REWORKING ALREADY
            DETECTED ERRORS (MD
    |

ASSPRD=PJDPRD*WTPJDP+PRDPRD*(1-WTPJDP)
    ~ TASKS/MAN-DAY
    ~       ASSUMED PRODUCTIVITY
    |

PRDPRD=CMTKDV/(CUMMD-CMTSMD)
    ~ TASKS/MAN-DAY
    ~       PERCEIVED DEVELOPMENT PRODUCTIVITY
    |

WTPJDP=MPWDEV*MPWREX
    ~ DIMENSIONLESS
    ~       WEIGHT TO PROJECTED DEVELOPMENT PRODUCTIVITY
    |

MPWDEV=TMPDEV(PJBPWK/100)
    ~ DIMENSIONLESS
    ~       MULTIPLIER TO PRODUCTIVITY WEIGHT DUE TO DEVELOMENT
    |

TMPDEV(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,1,1,1,1,1,0.975,0.9,0.75,0.5,0)
    ~ ~ |
```

MPWREX=TMPREX((1-MDPRNT/(JBSZMD-TSSZMD)))
~ DIMENSIONLESS
~ MULTIPLIER TO PRODUCTIVITY WEIGHT DUE TO RESOURCE EXPENDITURE
|

TMPREX(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,1,1,1,1,1,0.975,0.9,0.75,0.5,0)
~ ~ |

MDPNNT=TSKPRM/ASSPRD
~ MAN-DAYS
~ MAN DAYS PERCEIVED STILL NEEDED FOR NEW TASKS
|

TMDPSN=MDPNNT+MDPNTS+MDPNRW
~ MAN-DAYS
~ TOTAL MAN DAYS PERCEIVED STILL NEEDED
|

MDPNTS=TSTPRM/PRTPRD
~ MAN-DAYS
~ MAN DAYS PERCEIVED STILL NEEDED FOR TESTING
|

TSTPRM=PJBSZ-CUMTKT
~ TASKS
~ TASKS REMAINING TO BE TESTED
|

PRTPRD=SMOOTH((IF THEN ELSE(0 >= CUMTKT,PLTSPD,ACTSPD)),TSTSPD)
~ TASKS/MAN-DAY
~ PERCEIVED TESTING PRODUCTIVITY
|

TSTSPD=50
~ DAYS
~ TIME TO SMOOTH TESTING PRODUCTIVITY
|

PLTSPD=PJBSZ/TSSZMD
~ TASKS/MAN-DAY
~ PLANNED TESTING PRODUCTIVITY
|

ACTSPD=CUMTKT/(CMTSMD+0.001)
~ TASKS/MAN-DAY
~ ACTUAL TESTING PRODUCTIVITY |

```
PMDSHR=TMDPSN-MDRM
    ~ MAN DAYS
    ~       PERCEIVED SHORTAGE IN MAN DAYS
    |

SHRRPT=PMDSHR-MDHDL
    ~ MAN-DAYS
    ~       SHORTAGE REPORTED
    |

MDRPTN=MDRM+SHRRPT
    ~ MAN DAYS
    ~       MAN DAYS REPORTED STILL NEEDED
    |

SCHPR=(TMDPSN-MDRM)/MDRM
    ~ DIMENSIONLESS
    ~       SCHEDULE PRESSURE
    |

PTRPTC=ACTIVE INITIAL(SMOOTH((100-(MDRPTN/JBSZMD)*100),RPTDLY),0)
    ~ PERCENT
    ~       PERCENT OF TASKS REPORTED COMPLETE
    |

RPTDLY=10
    ~ DAYS
    ~       REPORTING DELAY
    |

PDEVRC=ACTIVE INITIAL(SMOOTH(MAX((100-((MDRPTN-MDPNTS)/(JBSZMD-
    TSSZMD))*100),PDEVRC),RPTDLY),0)
    ~
    ~        PERCENT DEVELOPMENT PERCEIVED COMPLETE %
    |

UNDJTK=INTEG((-RTDSTK),RJBSZ-PJBSZ)
    ~ TASKS
    ~       UNDISCOVERED JOB TASKS
    |

RJBSZ=INITIAL(RJBDSI/DSIPTK)
    ~ TASKS
    ~       REAL JOB SIZE IN TASKS
    |

RTDSTK=UNDJTK*PUTDPD/100
    ~ TASKS/DAY
    ~       RATE OF DISCOVERING TASKS     |
```

```
PUTDPD=TPUTDD(PJBPWK)
    ~ 1/DAY
    ~       PERCENT OF UNDISCOVERED TASKS DISCOVERED PER DAY
    |

TPUTDD(0,20,40,60,80,100,0,0.4,2.5,5,10,100)
    ~ ~ |

PJBPWK=(CMTKDV/PJBSZ)*100
    ~ PERCENT
    ~        PERCENT OF JOB PERCEIVED WORKED
    |

RTINCT=DELAY3(RTDSTK,DLINCT)
    ~ TASKS/DAY
    ~       RATE OF INCORPORATING DISCOVERED TASKS INTO PROJECT
    |

TKDSCV=INTEG((TIME STEP*(1/TIME STEP)*((-1)*TKDSCV+MAX((TKDSCV+TIME
    STEP*(RTDSTK-RTINCT)),0)))/TIME STEP,0)
    ~ TASKS
    ~       TASKS DISCOVERED
    |

DLINCT=10
    ~ DAYS
    ~       AVERAGE DELAY IN INCORPORATING DISCOVERED TASKS
    |

PJBSZ=INTEG(RTINCT,PJBDSI/DSIPTK)
    ~ TASKS
    ~       CURRENTLY PERCEIVED JOB SIZE
    |

TSKPRM=PJBSZ-CMTKDV
    ~ TASKS
    ~       NEW TASKS PERCEIVED REMAINING
    |

PSZDCT=TKDSCV/ASSPRD
    ~ MAN-DAYS
    ~       PERCEIVED SIZE OF DISCOVERED TASKS IN MAN DAYS
    |

RSZDCT=PSZDCT/(MDPRNT+0.0001)
    ~ DIMENSIONLESS
    ~       RELATIVE SIZE OF DISCOVERED TASKS
    |
```

FADHWO=TFAHWO(RSZDCT/(MSZTWO+0.001))
~
~ FRACTION OF ADDITIONAL TASKS ADDING TO MAN-DAYS
|

TFAHWO(0,0.2,0.4,0.6,0.8,1,1.2,1.4,1.6,1.8,2,0,0,0,0,0,0,0.7,0.9,0.975,1,1)
~ ~ |

MSZTWO=0.01
~
~ MAXIMUM RELATIVE SIZE OF ADDITIONS TOLERATED W/O ADDING TO PROJECT'
|

IRDVDT=(RTINCT/ASSPRD)*(FADHWO)
~
~ RATE OF INCREASE IN DEVELOPMENT MAN- DAYS DUE TO DISCOVERED TASKS
|

TSSZMD=INTEG((IRTSDT+(1/TIME STEP)*ARTJBM*IF THEN ELSE(FREFTS >= 0.9,1,0)),TSTMD)
~
~ PLANNED TESTING SIZE IN MAN-DAYS ... BEFORE WE START TESTING
|

IRTSDT=(RTINCT/PRTPRD)*(FADHWO)
~ MD/D
~ RATE OF INCREASE IN TESTING MAN DAYS DUE TO DISCOVERED TASKS
|

JBSZMD=TOTMD1
~ MAN DAYS
~ TOTAL JOB SIZE IN MAN DAYS
|

ARTJBM=(MDRPTN+CUMMD-JBSZMD)/DAJBMD
~ MAN-DAYS/DAY
~ RATE OF ADJUSTING THE JOB SIZE IN MAN-DAYS
|

DAJBMD=TDAJMD(TIMERM)
~ DAYS
~ DELAY IN ADJUSTING JOB'S SIZE IN MAN DAYS
|

TDAJMD(0,20,0.5,3) ~ ~ |

MDRM=MAX(0.0001,JBSZMD-CUMMD) ~ ~ |

```
{*******************************************************
   Planning and Man Days remaining
*******************************************************}

TIMEPR=MDRM/(WFS*ADMPPS)
   ~ DAYS
   ~      TIME PERCEIVED STILL REQUIRED
   |

INDCDT=Time+TIMEPR
   ~
   ~      INDICATED COMPLETION DATE
   |

SCHCDT=PROJDR
   ~
   ~      SCHEDULE COMPLETION DATE
   |

PROJDR=GAME(TDEVINI)
   ~ DAYS
   ~      PROJECT DURATION
   |

SCHADT=TSHADT(TIMERM)
   ~ DAYS
   ~      SCHEDULE ADJUSTMENT TIME
   |

TSHADT(0,5,0.5,5)
   ~ ~ |

TIMERM=MAX(SCHCDT-Time,0)
   ~ DAYS
   ~      TIME REMAINING
   |

WFINDC=(MDRM/(TIMERM+0.001))/ADMPPS
   ~ PEOPLE
   ~      INDICATED WORKFORCE
   |

WFNEED=MIN((WCWF*WFINDC+(1-WCWF)*TOTWF),WFINDC)
   ~ PEOPLE
   ~      WORKFORCE LEVEL NEEDED
   |
```

```
WCWF=MAX(WCWF1,WCWF2)
   ~ DIMENSIONLESS
   ~      WILLINGNESS TO CHANGE WORKFORCE LEVEL
   |

WCWF1=TWCWF1(TIMERM/WCWFTP)
   ~ DIMENSIONLESS
   ~      WILLINGNESS TO CHANGE WORKFORCE (1)
   |

TWCWF1(0,0.3,0.6,0.9,1.2,1.5,1.8,2.1,2.4,2.7,3,0,0,0.1,0.4,0.85,1,1,1,1,1,1)
   ~ ~ |

WCWFTP=IF THEN ELSE(TMPRMR = 0,HIREDY+ASIMDY,TMPRMR)
   ~
   ~      TIME PARAMETER DAYS
   |

TMPRMR=0
   ~
   ~      TIME PARAMETER ( = HIREDY+ASIMDY) DAYS
   |

WCWF2=TWCWF2(SCHCDT/MXTLCD)
   ~ DIMENSIONLESS
   ~      WILLINGNESS TO CHANGE WF (2)
   |

TWCWF2(0.86,0.88,0.9,0.92,0.94,0.96,0.98,1,0,0.1,0.2,0.35,0.6,0.7,0.77,0.8)
   ~ ~ |

MXTLCD=INITIAL(MXSCDX*TDEV)
   ~ DAYS
   ~      MAXIMUM TOLERABLE COMLETION DATE
   |

MXSCDX=1e+006
   ~ DIMENSIONLESS
   ~      MAX SCHEDULE COMPLETION DATE EXTENSION
   |
```

```
{********************************************************
    Sketch Information
********************************************************}

\\\---/// Sketch information - do not modify anything except names
V160  Do not put anything below this section - it will be ignored
*Logo
$Tms Rmn|10||0-0-0|0-0-0|0-0-0
|0,vskt0000.bmp,285,144,256,128,0,5,0,0,0,0,-1--1--1,-1--1--1
\\\---/// Sketch information - do not modify anything except names
V160  Do not put anything below this section - it will be ignored
*1
$Times New Roman|8|B|0-0-255|0-0-0|0-0-0
|0,"
Human Resources Mgmt
,246,54,30,30,2,131,0,6,0,0,Times New Roman|8|B|0-0-0,255-128-128,64-0-0
|1,"
Production
,247,166,32,32,2,131,0,6,0,1,Times New Roman|8|B|64-0-0,128-255-128,64-0-0
|2,"
Work Force Available
,242,102,55,7,0,3,0,3,-1,0,Arial|8|B|0-0-0,-1--1--1
|3,"
Planning
,367,232,30,30,2,131,0,6,0,0,Times New Roman|8|B|0-0-0,128-255-255,-1--1--1
|4,"
Controlling
,128,231,31,31,2,131,0,6,0,0,Times New Roman|8|B|0-0-0,255-128-192,-1--1--1
|5,"
SOFTWARE  DEVELOPMENT  MANAGEMENT  MODEL
,257,308,235,11,0,3,0,2,-1,0,Times New Roman|14|BU|0-64-128,-1--1--1
|6,"
Progress Status
,163,143,42,7,0,3,0,3,-1,0,Arial|8|B|0-0-0,-1--1--1
|7,"
Work Force Needed
,325,141,50,7,0,3,0,3,-1,0,Arial|8|B|0-0-0,-1--1--1
|8,"
Tasks Completed
,210,222,44,7,0,3,0,3,-1,0,Arial|8|B|0-0-0,-1--1--1
|9,"
Schedule
,298,223,25,7,0,3,0,3,-1,0,Arial|8|B|0-0-0,-1--1--1
|10,"
Effort Remaining
,250,263,43,7,0,3,0,3,-1,0,Arial|8|B|0-0-0,-1--1--1
-11
>0,1,0,0,0,0,0,-1--1--1,1|(246,101)|
>3,1,0,0,0,0,0,-1--1--1,1|(314,202)|
```

```
>3,0,1,0,0,0,0,-1--1--1,1|(366,110)|
>4,3,1,0,0,0,0,-1--1--1,1|(244,283)|
>4,0,1,0,0,0,0,-1--1--1,1|(141,92)|
>4,1,0,0,0,0,0,-1--1--1,1|(180,202)|
\\\---/// Sketch information - do not modify anything except names
V160  Do not put anything below this section - it will be ignored
*2
$Arial|8||0-0-0|0-0-0|0-0-0
|0,WFEXP,367,160,27,10,3,0,0,5,0,0,Arial|10|B|0-0-0,128-255-255,64-0-0
|1,ASIMDY,269,98,22,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,64-0-0
|2,WFNEW,198,160,32,10,3,0,0,5,0,0,Arial|10|B|0-0-0,128-255-255,64-0-0
|3,48,98,77,8,8,0,132,0,2,-1,0,Arial|8|B|0-0-0,64-0-0
|4,TIME STEP,275,187,29,7,0,0,0,7,-1,0,Arial|8|B|0-0-0,0-0-0,64-0-0
|5,TRNFRT,270,232,19,19,2,0,0,7,0,0,Arial|8|B|0-0-0,255-255-128,64-0-0
|6,48,207,281,8,8,0,132,0,2,-1,0,Arial|8|B|0-0-0,64-0-0
|7,48,430,40,8,8,0,132,0,2,-1,0,Arial|8|B|0-0-0,64-0-0
|8,1,225,220,12,5,39,131,0,0,0,0,2-1--1--1,0-0-160
|9,NEWTRR,190,220,23,7,32,0,0,2,-1,0,Arial|8|B|0-0-160,64-0-0
|10,2,281,154,6,9,39,131,0,0,0,0,1-1--1--1,0-0-160
|11,ASIMRT,281,170,21,7,32,0,0,2,-1,0,Arial|8|B|0-0-160,64-0-0
|12,FTEXWF,548,113,23,23,2,0,0,6,0,0,Arial|8|B|0-0-0,255-255-0,64-0-0
|13,WFS1,408,274,16,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,64-0-0
|14,WFSTRT,422,231,22,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,64-0-0
|15,AVEMPT,331,32,23,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,64-0-0
|16,1,318,100,9,5,39,131,0,0,0,0,4-1--1--1,0-0-160
|17,QUITRT,347,100,20,7,32,0,0,2,-1,0,Arial|8|B|0-0-160,0-0-160
|18,48,332,280,8,8,0,132,0,2,-1,0,Arial|8|B|0-0-0,64-0-0
|19,HIREDY,146,49,21,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,64-0-0
|20,WFGAP,386,326,19,19,2,0,0,6,0,0,Arial|8|B|0-0-0,255-255-128,64-0-0
|21,1,122,121,10,5,39,131,0,0,0,0,2-1--1--1,0-0-160
|22,HIRERT,92,121,20,7,32,0,0,2,-1,0,Arial|8|B|0-0-160,64-0-0
|23,TRNSDY,270,290,22,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,64-0-0
|24,1,317,220,11,5,39,131,0,0,0,0,4-1--1--1,0-0-160
|25,EXPTRR,350,220,22,7,32,0,0,2,-1,0,Arial|8|B|0-0-160,64-0-0
|26,ADMPPS,544,209,24,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,64-0-0
|27,CELNWH,452,126,19,19,2,0,0,7,0,0,Arial|8|B|0-0-0,255-255-0,64-0-0
|28,MNHPXS,475,95,24,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,64-0-0
|29,DMPTRN,189,80,22,22,2,0,0,6,0,0,Arial|8|B|0-0-0,255-255-128,64-0-0
|30,TRPNHR,270,52,22,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,64-0-0
|31,TOTWF,277,323,20,20,2,0,0,6,0,0,Arial|8|B|0-0-0,255-255-0,64-0-0
|32,CELTWF,468,201,19,19,2,0,0,6,0,0,Arial|8|B|0-0-0,255-255-0,64-0-0
|33,WFS,490,271,17,17,2,0,0,7,0,0,Arial|8|B|0-0-0,255-255-128,64-0-0
|34,"
Human Resources  Management Subsystem
,315,378,225,14,0,3,0,2,-1,0,Times New Roman|18|BU|0-0-160,-1--1--1
|35,WFSINI,420,286,27,7,0,1,1,2,-1,0,Times New Roman|8|B|128-128-128,128-128-128
>20,5,0,1,0,0,0,-1--1--1,1|(333,283)|
>23,5,0,0,0,0,0,-1--1--1,1|(270,274)|
>13,33,1,0,0,0,0,-1--1--1,1|(418,274)|
```

```
>32,33,0,0,0,0,0,-1--1--1,1|(476,229)|
>26,33,1,0,0,0,0,-1--1--1,1|(545,218)|
>33,20,0,0,0,0,0,-1--1--1,1|(444,294)|
>31,20,1,0,0,0,0,-1--1--1,1|(333,329)|
>0,32,1,0,0,0,0,-1--1--1,1|(419,178)|
>27,32,1,0,0,0,0,-1--1--1,1|(435,161)|
>2,31,1,0,0,0,0,-1--1--1,1|(168,192)|
>0,31,1,0,0,0,0,-1--1--1,1|(368,262)|
>2,29,0,0,0,0,0,-1--1--1,1|(194,132)|
>30,29,1,0,0,0,0,-1--1--1,1|(233,70)|
>28,27,1,0,0,0,0,-1--1--1,1|(488,127)|
>12,27,1,0,0,0,0,-1--1--1,1|(499,171)|
>0,12,1,0,0,0,0,-1--1--1,1|(456,62)|
>26,12,1,0,0,0,0,-1--1--1,1|(552,168)|
>4,24,1,0,0,0,0,-1--1--1,1|(283,196)|
>5,24,1,0,0,0,0,-1--1--1,1|(298,252)|
>24,18,0,0,0,0,0,-1--1--1,1|(322,241)|
>24,0,33,0,0,0,0,-1--1--1,1|(324,188)|
>0,24,1,0,0,0,0,-1--1--1,1|(348,194)|
>9,24,0,1,0,0,0,-1--1--1,1|(252,220)|
>3,21,32,0,0,0,0,-1--1--1,1|(110,100)|
>20,21,1,0,0,0,0,-1--1--1,1|(174,317)|
>19,21,1,0,0,0,0,-1--1--1,1|(140,73)|
>21,2,1,0,0,0,0,-1--1--1,1|(168,163)|
>13,14,1,0,0,0,0,-1--1--1,1|(417,241)|
>16,7,1,0,0,0,0,-1--1--1,1|(358,60)|
>16,0,33,0,0,0,0,-1--1--1,1|(345,140)|
>15,16,1,0,0,0,0,-1--1--1,1|(321,67)|
>0,16,1,0,0,0,0,-1--1--1,1|(326,147)|
>10,0,0,0,0,0,0,-1--1--1,1|(306,155)|
>14,0,1,0,0,0,0,-1--1--1,1|(412,212)|
>10,2,33,0,0,0,0,-1--1--1,1|(257,161)|
>2,10,1,0,0,0,0,-1--1--1,1|(259,135)|
>1,10,0,0,0,0,0,-1--1--1,1|(272,118)|
>8,6,0,0,0,0,0,-1--1--1,1|(218,242)|
>4,8,1,0,0,0,0,-1--1--1,1|(264,197)|
>5,8,1,0,0,0,0,-1--1--1,1|(250,252)|
>2,8,1,0,0,0,0,-1--1--1,1|(198,180)|
>8,2,33,0,0,0,0,-1--1--1,1|(218,180)|
>35,13,0,1,0,0,0,-1--1--1,1|(409,275)|
\\\---/// Sketch information - do not modify anything except names
V160  Do not put anything below this section - it will be ignored
*3
$Times New Roman|10||0-0-0|0-0-0|0-0-0
|0,DMPQA,216,88,20,20,2,0,0,6,0,0,Arial|8|B|0-0-0,255-255-128,0-0-0
|1,DMPATR,346,192,20,20,2,0,0,7,0,0,Arial|8|B|0-0-0,255-255-128,0-0-0
|2,FRMPQA,216,16,24,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|3,TOTDMP,345,87,20,20,2,0,0,7,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|4,ADMPPS,344,17,24,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
```

```
|5,TOTWF,477,87,21,21,2,1,0,7,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|6,DMPTRN,479,192,21,21,2,1,0,7,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|7,DMPRW,219,299,20,20,2,0,0,6,0,0,Arial|8|B|0-0-0,255-255-128,0-0-0
|8,DESECR,351,297,20,20,2,0,0,7,0,0,Arial|8|B|0-0-0,255-255-128,0-0-0
|9,DMPSWP,218,193,20,20,2,0,0,7,0,0,Arial|8|B|0-0-0,255-255-128,0-0-0
|10,PRWMPE,122,227,35,16,3,0,0,5,0,0,Arial|8|B|0-0-0,128-255-255,0-0-0
|11,DESRWD,350,236,24,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|12,DTCERR,482,297,19,19,2,1,0,7,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|13,RWMPPE,121,322,23,23,2,1,0,7,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|14,TARMPE,123,160,23,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|15,"
Manpower Allocation Sector
,318,367,130,13,0,3,0,2,-1,0,Times New Roman|16|BU|0-0-160,-1--1--1
>1,0,0,0,0,0,0,-1--1--1,1|(286,144)|
>2,0,0,0,0,0,0,-1--1--1,1|(216,38)|
>3,0,0,0,0,0,0,-1--1--1,1|(287,87)|
>4,3,0,0,0,0,0,-1--1--1,1|(344,38)|
>5,3,0,0,0,0,0,-1--1--1,1|(417,87)|
>6,1,0,0,0,0,0,-1--1--1,1|(419,192)|
>3,1,0,0,0,0,0,-1--1--1,1|(345,132)|
>9,7,0,0,0,0,0,-1--1--1,1|(218,238)|
>10,7,1,0,0,0,0,-1--1--1,1|(128,251)|
>1,9,0,0,0,0,0,-1--1--1,1|(289,192)|
>0,9,0,0,0,0,0,-1--1--1,1|(216,133)|
>11,8,0,0,0,0,0,-1--1--1,1|(350,253)|
>12,8,1,0,0,0,0,-1--1--1,1|(424,297)|
>13,10,1,0,0,0,0,-1--1--1,1|(119,281)|
>14,10,0,0,0,0,0,-1--1--1,1|(122,182)|
>8,7,1,0,0,0,0,-1--1--1,1|(291,297)|
\\\---/// Sketch information - do not modify anything except names
V160  Do not put anything below this section - it will be ignored
*4
$Times New Roman|10||0-0-0|0-0-0|0-0-0
|0,EXHLEV,457,206,24,10,3,0,0,6,0,0,Times New Roman|6|B|0-0-0,0-255-255,0-0-0
|1,RDEXHL,543,96,15,15,2,0,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-128,0-0-0
|2,PBWKRS,273,225,15,15,2,0,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-128,0-0-0
|3,AFMDPJ,369,109,26,10,3,0,0,7,0,0,Times New Roman|6|B|0-0-0,0-255-255,-1--1--1
|4,NFMDPJ,436,138,19,6,0,0,0,2,-1,0,Times New Roman|6|B|0-0-0,-1--1--1
|5,48,535,35,8,8,0,132,0,2,-1,0,Times New Roman|6|B|0-0-0,0-0-0
-6
|7,1,475,70,6,8,39,131,0,0,0,0,4-1--1--1,0-0-160
|8,RIEXHL,498,70,17,6,32,0,0,7,1,0,Times New Roman|6|B|0-0-160,0-255-255,0-0-160
-9
|10,EXHDDY,534,206,20,6,0,0,0,3,-1,0,Times New Roman|6|B|0-0-0,0-0-0
|11,WKRADY,280,171,16,16,2,1,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-232,0-0-0
|12,WKRTS,402,243,15,15,2,0,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-0,0-0-0
|13,1,350,177,6,8,39,131,0,0,0,0,4-1--1--1,0-0-255
|14,WRADJR,375,177,19,6,32,0,0,3,-1,0,Times New Roman|6|B|0-0-160,0-0-255
|15,FTEQWF,216,288,16,16,2,1,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-232,0-0-0
```

|16,MDHDL,209,138,16,16,2,0,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-128,0-0-0
|17,OVWDTH,438,306,14,14,2,0,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-128,0-0-0
|18,PMDSHR,266,303,18,18,2,1,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-232,0-0-0
|19,TMDPSN,216,225,15,15,2,1,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-232,0-0-0
|20,MODTEX,522,305,14,14,2,0,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-0,0-0-0
|21,NOVWDT,315,306,17,17,2,1,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-232,0-0-0
|22,MXEXHT,530,244,20,6,0,0,0,2,-1,0,Times New Roman|6|B|0-0-0,0-0-0
|23,CTRLSW,288,121,18,6,0,0,0,2,-1,0,Times New Roman|6|B|0-0-0,0-0-0
|24,EXSABS,172,183,15,15,2,0,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-0,0-0-0
|25,MAXSHR,121,246,18,18,2,0,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-128,0-0-0
|26,PMDSHR,79,194,17,17,2,1,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-232,0-0-0
|27,MDRM,170,245,16,16,2,1,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-232,0-0-0
|28,MPDMCL,435,32,16,16,2,0,0,6,0,0,Times New Roman|6|B|0-0-0,255-255-0,0-0-0
|29,COMMOH,344,29,16,16,2,0,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-0,0-0-0
|30,MAXMHR,98,305,22,6,0,0,0,2,-1,0,Times New Roman|6|B|0-0-0,0-0-0
|31,WTOVWK,147,325,18,18,2,1,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-232,0-0-0
|32,TOTWF,291,32,14,14,2,1,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-232,0-0-0
|33,SDVPRD,329,77,14,14,2,0,0,6,0,0,Times New Roman|6|B|0-0-0,255-255-128,0-0-0
|34,POTPRD,262,88,14,14,2,0,0,6,0,0,Times New Roman|6|B|0-0-0,255-255-128,0-0-0
|35,ANPPRD,240,39,16,16,2,0,0,6,0,0,Times New Roman|6|B|0-0-0,255-255-128,0-0-0
|36,MPPTPD,154,104,16,16,2,0,0,6,0,0,Times New Roman|6|B|0-0-0,255-255-0,0-0-0
|37,PJBAWK,87,123,17,17,2,1,0,6,0,0,Times New Roman|6|B|0-0-0,255-255-232,0-0-0
|38,FRWFEX,148,28,14,14,2,0,0,6,0,0,Times New Roman|6|B|0-0-0,255-255-0,0-0-0
|39,NPWPEX,108,65,19,6,0,0,0,2,-1,0,Times New Roman|6|B|0-0-0,0-0-0
|40,NPWPNE,110,84,18,6,0,0,0,2,-1,0,Times New Roman|6|B|0-0-0,0-0-0
|41,"
Software Development Productivity Subsector
,331,374,208,13,0,3,0,2,-1,0,Times New Roman|16|BU|0-0-160,0-0-0
|42,WFEXP,84,26,17,17,2,1,0,7,0,0,Times New Roman|6|B|0-0-0,255-255-232,0-0-0
-43
-44
-45
-46
-47
>1,0,1,0,0,0,0,-1--1--1,1|(537,144)|
>7,0,1,0,0,0,0,-1--1--1,1|(463,123)|
>4,7,1,0,0,0,0,-1--1--1,1|(460,98)|
>7,5,1,0,0,0,0,-1--1--1,1|(493,44)|
>10,1,1,0,0,0,0,-1--1--1,1|(544,160)|
>0,1,1,0,0,0,0,-1--1--1,1|(493,134)|
>7,1,1,0,0,0,0,-1--1--1,1|(496,92)|
>13,3,1,0,0,0,0,-1--1--1,1|(351,159)|
>11,13,1,0,0,0,0,-1--1--1,1|(306,185)|
>12,13,1,0,0,0,0,-1--1--1,1|(367,216)|
>3,13,1,0,0,0,0,-1--1--1,1|(337,139)|
>4,12,1,0,0,0,0,-1--1--1,1|(409,192)|
>2,12,0,0,0,0,0,-1--1--1,1|(330,232)|
>15,2,1,0,0,0,0,-1--1--1,1|(254,268)|
>16,2,1,0,0,0,0,-1--1--1,1|(246,185)|

```
>17,2,1,0,0,0,0,-1--1--1,1|(350,288)|
>18,2,1,0,0,0,0,-1--1--1,1|(275,253)|
>19,2,1,0,0,0,0,-1--1--1,1|(238,214)|
>20,17,1,0,0,0,0,-1--1--1,1|(473,312)|
>21,17,1,0,0,0,0,-1--1--1,1|(366,316)|
>0,20,1,0,0,0,0,-1--1--1,1|(464,252)|
>22,20,1,0,0,0,0,-1--1--1,1|(534,254)|
>23,16,1,0,0,0,0,-1--1--1,1|(284,126)|
>24,16,0,0,0,0,0,-1--1--1,1|(185,166)|
>25,16,1,0,0,0,0,-1--1--1,1|(166,146)|
>26,16,1,0,0,0,0,-1--1--1,1|(123,140)|
>27,24,1,0,0,0,0,-1--1--1,1|(160,219)|
>19,24,1,0,0,0,0,-1--1--1,1|(200,192)|
>15,25,1,0,0,0,0,-1--1--1,1|(165,279)|
>30,25,1,0,0,0,0,-1--1--1,1|(86,274)|
>17,25,1,0,0,0,0,-1--1--1,1|(270,342)|
>31,25,1,0,0,0,0,-1--1--1,1|(128,285)|
>3,28,1,0,0,0,0,-1--1--1,1|(380,75)|
>29,28,0,0,0,0,0,-1--1--1,1|(382,29)|
>32,29,1,0,0,0,0,-1--1--1,1|(308,46)|
>28,33,1,0,0,0,0,-1--1--1,1|(376,47)|
>34,33,1,0,0,0,0,-1--1--1,1|(295,99)|
>35,34,1,0,0,0,0,-1--1--1,1|(253,48)|
>36,34,1,0,0,0,0,-1--1--1,1|(201,94)|
>37,36,1,0,0,0,0,-1--1--1,1|(126,113)|
>38,35,1,0,0,0,0,-1--1--1,1|(187,34)|
>39,35,1,0,0,0,0,-1--1--1,1|(168,58)|
>40,35,1,0,0,0,0,-1--1--1,1|(174,74)|
>3,7,1,0,0,0,0,-1--1--1,1|(391,84)|
>32,38,1,0,0,0,0,-1--1--1,1|(213,11)|
>42,38,0,0,0,0,0,-1--1--1,1|(110,26)|
>4,3,0,0,0,0,0,-1--1--1,1|(413,128)|
\\\---/// Sketch information - do not modify anything except names
V160  Do not put anything below this section - it will be ignored
*5
$Arial|8||0-0-0|0-0-0|0-0-0
|0,QART,271,83,29,11,3,0,0,4,0,0,Arial|8|B|0-0-0,0-255-255,0-0-0
|1,AQADLY,336,51,23,7,0,0,0,3,-1,0,Arial|8|B|0-0-0,0-0-0
|2,SDVRT,379,76,20,20,2,1,0,7,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|3,"
Software Development Sector
,151,65,46,46,6,131,0,4,0,0,Arial|8|B|0-0-0,192-192-192,-1--1--1
-4
|5,PTDTER,286,119,31,12,3,0,0,7,0,0,Arial|8|B|0-0-0,0-255-255,0-0-0
|6,48,562,197,8,8,0,132,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|7,DTCERR,460,190,27,11,3,0,0,6,0,0,Arial|8|B|0-0-0,128-255-255,0-0-0
|8,SCHPR,108,246,16,16,2,0,1,6,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|9,MDRM,165,289,24,7,0,1,1,2,-1,0,Arial|8|B|0-0-0,0-0-0
|10,TMDPSN,88,249,29,7,0,1,1,2,-1,0,Arial|8|B|0-0-0,0-0-0
```

```
|11,SCHPR,458,73,20,20,2,1,0,7,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|12,DMPQA,279,249,22,22,2,1,0,7,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|13,"
Quality  Assurance  Sector
,323,392,120,13,0,3,0,2,-1,0,Times New Roman|16|BU|0-0-160,0-0-0
|14,ERRPTK,356,73,28,7,0,1,1,2,-1,0,Arial|8|B|0-0-0,0-0-0
|15,DMPRW,461,348,22,22,2,1,0,7,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|16,2,386,136,6,8,39,131,0,0,0,0,1-1--1--1,0-0-160
|17,ERRGRT,386,151,23,7,32,0,0,2,-1,0,Arial|8|B|0-0-160,0-0-160
|18,PERDRT,328,313,19,19,2,0,0,7,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|19,ANERPT,229,170,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|20,TIME STEP,277,208,29,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|21,1,355,211,6,9,39,131,0,0,0,0,4-1--1--1,0-0-160
|22,ERRDRT,383,211,22,7,32,0,0,2,2,0,Arial|8|B|0-0-160,0-0-160
|23,1,73,144,6,8,39,131,0,0,0,0,2-1--1--1,0-0-160
|24,ERRSRT,45,144,22,7,32,0,0,2,3,0,Arial|8|B|0-0-160,0-0-160
|25,QAMPNE,221,248,18,18,2,0,0,7,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|26,MDEFED,137,287,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|27,MPDMCL,181,216,21,21,2,1,0,7,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|28,NQAMPE,225,322,18,18,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|29,PJBAWK,168,353,22,22,2,1,0,7,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|30,ERRDSY,110,213,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|31,ANERPT,29,325,28,7,0,1,1,2,-1,0,Arial|8|B|0-0-0,0-0-0
|32,DSIPTK,59,233,20,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|33,TSKWK,131,156,26,7,0,1,1,2,-1,0,Arial|8|B|0-0-0,0-0-0
|34,"
System Testing Sector
,532,93,36,36,6,131,0,4,0,0,Arial|8|B|0-0-0,192-192-192,-1--1--1
|35,RWMPPE,390,349,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-128,0-0-0
|36,48,463,133,8,8,0,132,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|37,1,462,256,6,8,39,131,0,0,0,0,2-1--1--1,0-0-160
|38,RWRATE,433,256,23,7,32,0,0,2,-1,0,Arial|8|B|0-0-160,0-0-160
|39,MPDMCL,376,268,23,23,2,1,0,7,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|40,NRWMPE,280,349,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|41,PJBAWK,106,358,30,7,0,1,1,2,-1,0,Arial|8|B|0-0-0,0-0-0
|42,NERPTK,83,282,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|43,CMRWED,531,356,29,10,3,0,0,5,0,0,Arial|8|B|0-0-0,128-255-255,0-0-0
|44,NERPK,84,354,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-128,0-0-0
-45
|46,PBADFX,534,316,23,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|47,1,530,258,6,8,39,131,0,0,0,0,4-1--1--1,0-0-160
|48,BDFXGR,559,258,23,7,32,0,0,2,-1,0,Arial|8|B|0-0-160,0-0-160
-49
>1,0,1,0,0,0,0,-1--1--1,1|(301,53)|
>2,0,1,0,0,0,0,-1--1--1,1|(343,81)|
>9,8,0,1,0,0,0,-1--1--1,1|(143,272)|
>10,8,0,1,0,0,0,-1--1--1,1|(111,245)|
>2,16,1,0,0,0,0,-1--1--1,1|(384,96)|
>2,17,1,1,0,0,0,-1--1--1,1|(273,65)|
```

```
>14,16,0,1,0,0,0,-1--1--1,1|(367,97)|
>5,21,1,0,0,0,0,-1--1--1,1|(300,162)|
>21,7,1,0,0,0,0,-1--1--1,1|(419,182)|
>18,21,1,0,0,0,0,-1--1--1,1|(331,254)|
>20,21,1,0,0,0,0,-1--1--1,1|(305,208)|
>5,21,33,0,0,0,0,-1--1--1,1|(329,143)|
>16,5,1,0,0,0,0,-1--1--1,1|(338,126)|
>0,23,1,0,0,0,0,-1--1--1,1|(219,106)|
>23,5,1,0,0,0,0,-1--1--1,1|(187,137)|
>19,23,1,0,0,0,0,-1--1--1,1|(110,159)|
>12,18,1,0,0,0,0,-1--1--1,1|(300,269)|
>25,18,1,0,0,0,0,-1--1--1,1|(255,287)|
>26,25,1,0,0,0,0,-1--1--1,1|(169,276)|
>27,25,1,0,0,0,0,-1--1--1,1|(220,208)|
>28,25,1,0,0,0,0,-1--1--1,1|(222,284)|
>29,28,1,0,0,0,0,-1--1--1,1|(180,306)|
>30,26,1,0,0,0,0,-1--1--1,1|(137,240)|
>31,30,0,1,0,0,0,-1--1--1,1|(61,279)|
>32,30,1,0,0,0,0,-1--1--1,1|(65,217)|
>5,19,1,0,0,0,0,-1--1--1,1|(273,154)|
>33,19,1,1,0,0,0,-1--1--1,1|(217,197)|
>37,7,1,0,0,0,0,-1--1--1,1|(440,227)|
>39,35,1,0,0,0,0,-1--1--1,1|(390,294)|
>40,35,1,0,0,0,0,-1--1--1,1|(324,366)|
>29,40,1,0,0,0,0,-1--1--1,1|(205,362)|
>15,37,0,0,0,0,0,-1--1--1,1|(461,302)|
>35,37,0,0,0,0,0,-1--1--1,1|(424,304)|
>32,42,1,0,0,0,0,-1--1--1,1|(60,254)|
>44,42,1,0,0,0,0,-1--1--1,1|(50,319)|
>29,44,1,0,0,0,0,-1--1--1,1|(124,358)|
>37,43,1,0,0,0,0,-1--1--1,1|(484,299)|
>46,47,1,0,0,0,0,-1--1--1,1|(532,293)|
>37,47,0,0,0,0,0,-1--1--1,1|(489,256)|
>47,34,0,0,0,12,0,-1--1--1,1|(530,197)|
>0,34,4,0,0,12,0,-1--1--1,4|(271,29)|(532,29)|(532,22)|(532,22)|
>23,34,4,0,0,12,0,-1--1--1,5|(73,45)|(73,45)|(73,11)|(532,11)|(532,11)|
>3,0,1,0,0,12,0,-1--1--1,1|(206,59)|
>16,36,33,0,0,0,0,-1--1--1,1|(448,134)|
>47,6,33,0,0,0,0,-1--1--1,1|(542,221)|
>22,5,0,0,0,0,0,-1--1--1,1|(342,172)|
\\\---/// Sketch information - do not modify anything except names
V160  Do not put anything below this section - it will be ignored
*6
$Arial|8||0-0-0|0-0-0|0-0-0
|0,UDAVER,266,132,30,13,3,0,0,5,0,0,Arial|8|B|0-0-0,128-255-255,0-0-0
|1,BDFXGR,165,308,18,18,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-128,0-0-0
|2,AERRDS,360,47,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|3,UDPVER,300,318,29,11,3,0,0,4,0,0,Arial|8|B|0-0-0,0-255-255,0-0-0
|4,MPDMCL,569,100,21,21,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
```

```
|5,2,130,104,6,8,39,131,0,0,0,0,1-1--1--1,0-0-160
|6,AERGRT,130,119,23,7,32,0,0,2,-1,0,Arial|8|B|0-0-160,0-0-160
|7,MAERED,81,51,28,12,3,0,0,5,0,0,Arial|8|B|0-0-0,128-255-255,0-0-0
|8,SDVRT,69,103,20,20,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|9,TSAEDS,182,45,23,8,0,0,0,5,0,0,Arial|8|B|0-0-0,0-0-64,0-0-0
|10,2,104,176,6,8,39,131,0,0,0,0,2-1--1--1,0-0-160
|11,AEGRT,79,176,19,7,32,0,0,2,-1,0,Arial|8|B|0-0-160,0-0-160
|12,ERRSRT,71,228,19,19,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|13,FRAERR,164,211,18,18,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-128,0-0-0
|14,48,71,145,8,8,0,132,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|15,48,513,281,8,8,0,132,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|16,TMPNPE,429,37,23,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|17,ERRDSY,121,368,17,17,2,0,1,5,0,0,Arial|8||128-64-0,255-255-128,0-128-0
|18,QART,177,293,23,8,0,1,1,1,-1,0,128-128-128,128-128-128
|19,1,351,182,6,8,39,131,0,0,0,0,2-1--1--1,0-0-160
|20,DCRTAE,323,182,22,7,32,0,0,2,-1,0,Arial|8|B|0-0-160,0-0-160
|21,TIME STEP,375,264,29,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|22,ANERPT,98,351,29,8,0,1,1,1,-1,0,128-128-128,128-128-128
|23,PBADFX,52,66,29,8,0,1,1,1,-1,0,128-128-128,128-128-128
|24,RWRATE,44,107,30,8,0,1,1,1,-1,0,128-128-128,128-128-128
|25,PJBAWK,52,384,29,8,0,1,1,1,-1,0,128-128-128,128-128-128
|26,AERRFR,223,232,19,19,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|27,PJBAWK,211,168,21,21,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|28,1,282,263,6,8,39,131,0,0,0,0,1-1--1--1,0-0-160
|29,AERRRT,282,279,23,8,32,0,0,5,0,0,Arial|8|B|0-0-160,0-0-0,0-0-160
|30,QART,512,61,23,8,0,1,1,1,-1,0,128-128-128,128-128-128
|31,48,246,86,8,8,0,132,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|32,2,449,315,6,8,39,131,0,0,0,0,1-1--1--1,0-0-160
|33,DCRTPE,449,330,22,7,32,0,0,2,-1,0,Arial|8|B|0-0-160,0-0-160
|34,ANERPT,166,309,29,8,0,1,1,1,-1,0,128-128-128,128-128-128
|35,DMPTST,396,169,22,22,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|36,TMPNPT,461,88,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-128,0-0-0
|37,2,230,296,6,8,39,131,0,0,0,0,1-1--1--1,0-0-160
|38,PEGRT,230,311,19,7,32,0,0,2,-1,0,Arial|8|B|0-0-160,0-0-160
|39,QART,47,332,23,8,0,1,1,1,-1,0,128-128-128,128-128-128
|40,TSTOVH,548,49,22,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|41,DSIPTK,125,116,21,8,0,0,1,1,-1,0,0-0-255,128-128-128
|42,PERRDS,518,124,20,20,2,0,0,4,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|43,CUMTQA,496,198,31,12,3,0,0,5,0,0,Arial|8|B|0-0-0,128-255-255,0-0-0
|44,1,472,261,6,8,39,131,0,0,0,0,4-1--1--1,0-0-160
|45,TSRATE,501,261,23,8,32,0,0,5,0,0,Arial|8|B|0-0-160,0-0-0,0-0-160
|46,"
QA & Rework Sector
,73,310,33,33,6,131,0,4,0,0,Arial|8|B|0-0-0,192-192-192,0-0-0
|47,"
System Testing Sector
,310,374,101,13,0,3,0,2,-1,0,Times New Roman|16|BU|0-0-160,0-0-0
>10,0,1,0,0,0,0,-1--1--1,1|(210,128)|
>1,10,1,0,0,0,0,-1--1--1,1|(126,234)|
```

```
>12,10,1,0,0,0,0,-1--1--1,1|(92,205)|
>13,10,1,0,0,0,0,-1--1--1,1|(119,188)|
>14,10,33,0,0,0,0,-1--1--1,1|(91,154)|
>19,0,1,0,0,0,0,-1--1--1,1|(303,145)|
>9,5,1,0,0,0,0,-1--1--1,1|(146,67)|
>7,5,1,0,0,0,0,-1--1--1,1|(107,76)|
>2,5,1,0,0,0,0,-1--1--1,1|(176,75)|
>8,5,0,0,0,0,0,-1--1--1,1|(99,103)|
>0,19,1,0,0,0,0,-1--1--1,1|(318,127)|
>21,19,1,0,0,0,0,-1--1--1,1|(353,221)|
>2,19,1,0,0,0,0,-1--1--1,1|(374,107)|
>23,1,0,1,0,0,0,-1--1--1,1|(103,176)|
>24,1,0,1,0,0,0,-1--1--1,1|(97,197)|
>27,26,1,0,0,0,0,-1--1--1,1|(231,179)|
>0,28,1,0,0,0,0,-1--1--1,1|(292,199)|
>28,0,1,0,0,0,0,-1--1--1,1|(260,200)|
>26,28,1,0,0,0,0,-1--1--1,1|(242,253)|
>32,3,1,0,0,0,0,-1--1--1,1|(396,323)|
>15,32,34,0,0,0,0,-1--1--1,1|(489,300)|
>31,5,33,0,0,0,0,-1--1--1,1|(187,95)|
>43,2,0,0,0,0,0,-1--1--1,1|(434,128)|
>0,2,1,0,0,0,0,-1--1--1,1|(289,91)|
>2,7,1,0,0,0,0,-1--1--1,1|(294,32)|
>41,7,1,1,0,0,0,-1--1--1,1|(103,109)|
>9,7,1,0,0,0,0,-1--1--1,1|(133,53)|
>37,3,1,0,0,0,0,-1--1--1,1|(257,291)|
>43,42,1,0,0,0,0,-1--1--1,1|(498,152)|
>3,42,0,1,0,0,0,-1--1--1,1|(402,226)|
>30,43,1,1,0,0,0,-1--1--1,1|(594,115)|
>34,17,1,1,0,0,0,-1--1--1,1|(159,345)|
>41,17,1,1,0,0,0,-1--1--1,1|(139,278)|
>2,36,1,0,0,0,0,-1--1--1,1|(406,67)|
>41,36,0,1,0,0,0,-1--1--1,1|(286,102)|
>4,36,1,0,0,0,0,-1--1--1,1|(509,87)|
>42,36,1,0,0,0,0,-1--1--1,1|(490,106)|
>16,36,1,0,0,0,0,-1--1--1,1|(459,40)|
>40,36,1,0,0,0,0,-1--1--1,1|(509,61)|
>43,44,2,0,0,0,0,-1--1--1,1|(497,227)|
>44,43,1,0,0,0,0,-1--1--1,1|(477,221)|
>12,37,1,0,0,0,0,-1--1--1,1|(107,248)|
>1,37,1,0,0,0,0,-1--1--1,1|(191,308)|
>13,37,1,0,0,0,0,-1--1--1,1|(190,247)|
>35,44,1,0,0,0,0,-1--1--1,1|(404,197)|
>36,44,1,0,0,0,0,-1--1--1,1|(427,162)|
>21,44,1,0,0,0,0,-1--1--1,1|(431,264)|
>44,19,1,0,0,0,0,-1--1--1,1|(387,229)|
>28,3,1,0,0,0,0,-1--1--1,1|(308,260)|
>22,12,0,1,0,0,0,-1--1--1,1|(87,301)|
>39,12,0,1,0,0,0,-1--1--1,1|(55,291)|
```

```
>27,13,1,0,0,0,0,-1--1--1,1|(175,162)|
>44,32,1,0,0,0,0,-1--1--1,1|(458,274)|
>3,32,1,0,0,0,0,-1--1--1,1|(359,297)|
>21,32,1,0,0,0,0,-1--1--1,1|(413,283)|
>42,32,1,0,0,0,0,-1--1--1,1|(536,304)|
>5,0,1,0,0,0,0,-1--1--1,1|(181,105)|
>46,43,4,0,0,12,1,0-0-0,5|(73,354)|(559,354)|(559,196)|(552,196)|(539,196)|
>46,12,3,0,0,12,1,0-0-0,1|(71,278)|
>46,1,3,0,0,12,1,0-0-0,1|(106,309)|
\\\---/// Sketch information - do not modify anything except names
V160  Do not put anything below this section - it will be ignored
*7
$Arial|8||0-0-0|0-0-0|0-0-0
|0,ASSPRD,52,219,17,17,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|1,MDPNRW,179,158,18,18,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|2,TSKPRM,116,176,22,22,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|3,PRMD,292,172,23,8,0,1,1,1,-1,0,128-128-128,128-128-128
|4,MDHDL,316,106,20,20,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|5,MDRPTN,379,73,18,18,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-128,0-0-0
|6,MDRM,240,130,19,19,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|7,SHRRPT,305,55,18,18,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|8,PMDSHR,235,47,17,17,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|9,MDPNNT,56,148,18,18,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|10,TMDPSN,91,57,17,17,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|11,DTCERR,135,87,19,19,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|12,MDPNTS,475,55,18,18,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|13,PRWMPE,197,92,22,22,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|14,PJDPRD,205,221,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|15,PRDPRD,251,285,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|16,WTPJDP,53,299,18,18,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|17,MDPRNT,283,228,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|18,PJBPWK,377,321,29,8,0,1,1,1,-1,0,128-128-128,128-128-128
|19,CMTKDV,153,284,21,21,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|20,CMTSMD,344,219,24,24,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|21,CUMMD,313,298,22,22,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|22,MPWDEV,207,311,18,18,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|23,MPWREX,96,264,22,22,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|24,PRTPRD,497,192,32,12,3,0,0,5,0,0,Arial|8|B|0-0-0,0-255-255,0-0-0
|25,TSTPRM,548,305,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|26,ACTSPD,430,133,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|27,CUMTKT,366,303,24,24,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|28,PLTSPD,464,257,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|29,TSTSPD,483,122,21,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|30,"
Controlling Subsystem
",301,359,102,13,0,3,0,2,-1,0,Times New Roman|16|BU|0-0-160,-1--1--1
|31,PJBSZ,422,293,20,20,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|32,TSSZMD,531,238,20,20,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
-33
```

```
>6,5,1,0,0,0,0,-1--1--1,1|(269,144)|
>7,5,1,0,0,0,0,-1--1--1,1|(342,39)|
>4,7,1,0,0,0,0,-1--1--1,1|(273,86)|
>8,7,1,0,0,0,0,-1--1--1,1|(269,35)|
>6,8,1,0,0,0,0,-1--1--1,1|(246,89)|
>10,8,1,0,0,0,0,-1--1--1,1|(158,55)|
>9,10,1,0,0,0,0,-1--1--1,1|(63,93)|
>1,10,1,0,0,0,0,-1--1--1,1|(105,124)|
>12,10,1,0,0,0,0,-1--1--1,1|(332,18)|
>11,1,1,0,0,0,0,-1--1--1,1|(144,115)|
>13,1,1,0,0,0,0,-1--1--1,1|(180,108)|
>0,9,0,0,0,0,0,-1--1--1,1|(52,190)|
>2,9,1,0,0,0,0,-1--1--1,1|(98,167)|
>14,0,1,0,0,0,0,-1--1--1,1|(149,212)|
>15,0,1,0,0,0,0,-1--1--1,1|(188,255)|
>16,0,1,0,0,0,0,-1--1--1,1|(52,252)|
>17,14,0,0,0,0,0,-1--1--1,1|(250,225)|
>2,14,0,0,0,0,0,-1--1--1,1|(154,194)|
>19,15,1,0,0,0,0,-1--1--1,1|(200,279)|
>20,15,1,0,0,0,0,-1--1--1,1|(297,268)|
>21,15,1,0,0,0,0,-1--1--1,1|(267,322)|
>22,16,1,0,0,0,0,-1--1--1,1|(132,323)|
>23,16,1,0,0,0,0,-1--1--1,1|(85,296)|
>24,12,1,0,0,0,0,-1--1--1,1|(515,139)|
>25,12,1,0,0,0,0,-1--1--1,1|(546,117)|
>1,17,0,0,0,0,0,-1--1--1,1|(223,188)|
>12,17,1,0,0,0,0,-1--1--1,1|(445,72)|
>6,17,1,0,0,0,0,-1--1--1,1|(271,187)|
>18,22,0,1,0,0,0,-1--1--1,1|(292,316)|
>26,24,0,0,0,0,0,-1--1--1,1|(458,158)|
>27,24,1,0,0,0,0,-1--1--1,1|(424,205)|
>28,24,1,0,0,0,0,-1--1--1,1|(493,227)|
>29,24,1,0,0,0,0,-1--1--1,1|(484,130)|
>27,25,1,0,0,0,0,-1--1--1,1|(411,322)|
>31,25,1,0,0,0,0,-1--1--1,1|(481,305)|
>31,28,1,0,0,0,0,-1--1--1,1|(423,262)|
>32,28,1,0,0,0,0,-1--1--1,1|(501,280)|
>20,26,1,0,0,0,0,-1--1--1,1|(372,157)|
>27,26,1,0,0,0,0,-1--1--1,1|(396,180)|
\\\---/// Sketch information - do not modify anything except names
V160  Do not put anything below this section - it will be ignored
*8
$Arial|8||0-0-0|0-0-0|0-0-0
|0,WFS,388,45,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|1,ADMPPS,243,82,24,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|2,CELTWF,193,45,20,20,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|3,WFS1,313,156,22,8,0,1,1,1,-1,0,128-128-128,128-128-128
|4,WFNEED,199,124,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|5,TOTWF,107,50,20,20,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
```

```
|6,WCWF,85,121,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|7,WFINDC,331,121,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|8,WCWF1,217,188,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|9,MDRM,422,120,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|10,Time,408,188,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|11,WCWF2,82,280,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|12,TIMERM,304,188,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-0,0-0-0
|13,WCWFTP,127,199,20,20,2,0,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|14,MXTLCD,257,248,20,20,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|15,SCHCDT,393,278,31,11,3,0,0,5,0,0,Arial|8|B|0-0-0,128-255-255,0-0-0
|16,PROJDR,489,250,23,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|17,INITIAL TIME,486,214,33,7,0,0,0,2,-1,0,Arial|8|B|0-0-0,0-0-0
|18,CUMMD,489,163,20,20,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|19,JBSZMD,480,47,22,22,2,1,0,5,0,0,Arial|8|B|0-0-0,255-255-232,0-0-0
|20,ASIMDY,148,155,28,8,0,1,1,1,-1,0,128-128-128,128-128-128
|21,HIREDY,205,215,27,8,0,1,1,1,-1,0,128-128-128,128-128-128
|22,TMPRMR,244,197,31,8,0,1,1,1,-1,0,128-128-128,128-128-128
|23,"
Planning Subsystem
",294,329,91,13,0,3,0,2,-1,0,Times New Roman|16|BU|0-0-160,-1--1--1
|24,TDEVINI,509,296,29,8,0,1,1,1,-1,0,128-128-128,128-128-128
>1,0,1,0,0,0,0,-1--1--1,1|(305,72)|
>2,0,0,0,0,0,0,-1--1--1,1|(283,45)|
>3,0,0,1,0,0,0,-1--1--1,1|(343,110)|
>5,4,0,0,0,0,0,-1--1--1,1|(147,82)|
>6,4,0,0,0,0,0,-1--1--1,1|(134,121)|
>7,4,0,0,0,0,0,-1--1--1,1|(271,121)|
>1,7,1,0,0,0,0,-1--1--1,1|(289,90)|
>9,7,0,0,0,0,0,-1--1--1,1|(383,120)|
>12,7,1,0,0,0,0,-1--1--1,1|(347,158)|
>8,6,0,0,0,0,0,-1--1--1,1|(157,157)|
>11,6,0,0,0,0,0,-1--1--1,1|(82,207)|
>12,8,0,0,0,0,0,-1--1--1,1|(267,188)|
>13,8,1,0,0,0,0,-1--1--1,1|(175,227)|
>14,11,0,0,0,0,0,-1--1--1,1|(176,262)|
>15,11,1,0,0,0,0,-1--1--1,1|(238,278)|
>16,15,0,0,0,0,0,-1--1--1,1|(451,260)|
>15,12,0,0,0,0,0,-1--1--1,1|(355,239)|
>10,12,0,0,0,0,0,-1--1--1,1|(363,188)|
>17,10,0,0,0,0,0,-1--1--1,1|(452,202)|
>18,9,0,0,0,0,0,-1--1--1,1|(461,145)|
>19,9,0,0,0,0,0,-1--1--1,1|(454,78)|
>20,13,0,1,0,0,0,-1--1--1,1|(143,165)|
>21,13,0,1,0,0,0,-1--1--1,1|(168,207)|
>22,13,0,1,0,0,0,-1--1--1,1|(186,197)|
>24,16,0,1,0,0,0,-1--1--1,1|(501,278)|
```

```
\\\---/// Sketch information - do not modify anything except names
V160  Do not put anything below this section - it will be ignored
*System
$Tms Rmn|10||0-0-0|0-0-0|0-0-0
|0,vskt0001.bmp,298,174,205,174,0,5,0,0,0,0,-1--1--1,-1--1--1
|1,"
System Dynamics Primer
",302,371,160,16,0,3,0,2,-1,0,Arial|20|B|0-64-128,-1--1--1
-2
```

APPENDIX B.

SMFS VENSIM GRAPH DESCRIPTION (VGD) FILE

This appendix provides a listing of the pre-defined reports, help, and information screens and graphs available in the SMFS User Interface. These reports, graphs, and screens are contained in the Causal.vgd file. A Vensim graph description file allows the creation of customized output formats. It is a file that contains a series of keywords and values that describe what is to be displayed in a graph, table, or text report. The .vgd file structure and syntax depend on the commands used within the file, since each tool can contain different information. Further information about the various commands available can be found in Ventana [1994, p. 259-270]. The listing that follows provides the elements used within the SMFS .vgd file to display information and simulation results.

:REPORT SYSTEM
:TITLE System Dynamics Primer
:LOCATION -1,-1
:SIZE 64, 26

System Dynamics is a methodology for studying problems arising from the dynamic behavior of management and socioeconomic systems. The principal concern of a System Dynamics study is to understand the forces operating in a system in order to:

a. Determine the forces that influence on the stability of the system.
b. Determine the structure of the system as it relates to dynamic behavior such as growth, decline, or oscillation of central forces of interest.
c. Determine how the structure of a system can be modified to avoid unwanted situations or potentially dangerous conditions, and promote a better behavior.

The basic structure of a system dynamic model consists of a number of reservoirs or levels, interconnected by arrows representing information flow paths. The rate of information flow is controlled by functions that depend upon conditions in the system. The following are basic elements of a system dynamics model:

a. Levels or reservoirs - represented in diagrams as a boxes. Level variables are determined through the accumulation of information flow. They are always dependent upon rate variables. They represent an accumulation, or integration over time of flows or changes that come into and go out of the level.

b. Rates - rate variables represent the instantaneous flow to or from a level variable. They

are represented by a valve symbol to indicate control. Rate variable equations determine how the flow rates depends upon levels.

c. Auxiliary variables - represent intermediary variables that can occur anywhere in a path directed from a level to a rate. They represent intermediate values used in computing level and rate dependencies. Another view of auxiliary variables are as the combinations of information inputs into concepts. They are represented in diagrams as bubbles or circles.

d. Constants - are used to define fixed parameters in a model. They are represented as text labels.

e. Information flow - lines with arrow heads indicate the flow of information from one point to another. The represent a cause and effect between two variables.

f. Sources and Sinks - are represented by clouds. The represent the origin or termination of flows without any interest or consequence to the system model.

These basic elements are employed in developing feedback or causal-loop diagrams. The diagram is an aid used to determine the system structure and the presence of feedback loops. Feedback loops are either positive or negative. A positive feedback loop is usually associated with system growth, while negative feedback loops tend to stabilize the system and attain a particular state.

Causal-Loop Diagrams are the graphical equivalents of a system dynamics model set in mathematical equations. These diagrams have the advantage of showing system structure clearly,
while emphasizing the presence and effect of feedback loops.
:END-OF-REPORT

:REPORT INFO
:TITLE Model Overview
:LOCATION 1,1
:SIZE 54,15

This model represents a comprehensive system-dynamics model of the management process for software development. System dynamics is a methodology for studying the dynamic behavior of systems. It prescribes a set of concepts and procedures to assist in creating and testing system policies within the model. The model emphasizes the dependence of dynamic behavior upon information feedback within the cause and effect structure of the dynamics of the software development and management processes.

The model integrates four major subsystems covering the typical management functions of organizing, planning and controlling resources with the software production activities of design, coding and testing. The figure is a high level view of the four subsystems and their interconnections.

For an in-depth detail description of the model and its subsystems, please refer to "Software Project Dynamics, An integrated Approach", by Tarek K. Abdel-Hamid and Stuart E. Madnick.
:END-OF-REPORT

:REPORT INFO1
:TITLE Human Resources Subsystem
:LOCATION -1,-1
:SIZE 54,10

This subsystem captures the hiring, training, assimilation, and transfer of people within the organization. The diagram illustrates the project's human resources as composed of two major work force levels named WFNEW and WEXP, for new hired work force and the experienced work force, respectively. Additionally, all the activities that affect these levels, as well as their feedback loops are shown in the diagram.

A more detail description of the subsystem can be found in "Software Project Dynamics, An Integrated Approach", by Tarek K. Abdel-Hamid and Stuart E. Madnick.
:END-OF-REPORT

:REPORT INFO2
:TITLE Manpower Allocation Sector
:LOCATION -1,-1
:SIZE 54,9

This diagram represents the manpower allocations in the areas of quality assurance, production workload, and retesting. This sector is one of four sectors that comprise the Software production subsystem, one of the major activities of a software development project. The diagram depicts not only the information variables, but also their feedback flows.

A more detail description of the sector and related subsystems can be found in "Software Project Dynamics, An integrated Approach", by Tarek K. Abdel-Hamid and Stuart E. Madnick.
:END-OF-REPORT

:REPORT INFO3
:TITLE Software Development Productivity Subsector
:LOCATION -1,-1
:SIZE 54,10

This diagram illustrates the productivity subsector of software production as a function of complex factors affecting how much manpower is used and how productive they are. This sector is one of four sectors that comprise the Software production subsystem, one of the major activities of a software development project. The diagram depicts not only the information variables, but also their feedback flows.

A more detail description of the sector and related subsystems can be found in "Software Project Dynamics, An integrated Approach", by Tarek K. Abdel-Hamid and Stuart E. Madnick.
:END-OF-REPORT

:REPORT INFO4
:TITLE Quality Assurance Sector
:LOCATION -1,-1
:SIZE 54,13

This diagram illustrates the software quality assurance sector of software production as a function of complex factors in the generation, detection, and correction of errors during the development phase.

The sector includes activities related to the design, coding, reviewing, and testing, but excludes requirement definition activities, as they are assumed completed. This sector is one of four sectors that comprise the Software production subsystem, one of the major activities of a software development project. The diagram depicts not only the information variables, but also their feedback flows and interrelationships with other subsystems.

A more detailed description of the sector and related subsystems can be found in "Software Project Dynamics, An integrated Approach", by Tarek K. Abdel-Hamid and Stuart E. Madnick.
:END-OF-REPORT

:REPORT INFO5
:TITLE System Testing Sector
:LOCATION -1,-1
:SIZE 54,12

This diagram illustrates the system testing sector of software production as a function of two processes: the growth of the undetected error populations and the system testing that result in the detection and correction of those errors.

This sector is one of four sectors that comprise the Software production subsystem, one of the major activities of a software development project. The diagram depicts not only the information variables, but also their feedback flows and interrelationships with other subsystems.

A more detailed description of the sector and related subsystems can be found in "Software Project Dynamics, An integrated Approach", by Tarek K. Abdel-Hamid and Stuart E. Madnick.
:END-OF-REPORT

:REPORT INFO6
:TITLE Controlling Subsystem
:LOCATION -1,-1
:SIZE 54,13

This diagram illustrates the controlling subsystem of the model as a function of three major functions: measurement of what is happening in the activity being controlled, evaluating the significance of the measurements reported against a set of standards, and reporting what has been measured and assessed so corrective action can take place, if needed.

This sector is one of four subsystems that comprise the software development and management model. The diagram depicts not only the information variables, but also their feedback flows and interrelationships with other sectors and subsystems.

A more detailed description of the sector and related subsystems can be found in "Software Project Dynamics, An integrated Approach", by Tarek K. Abdel-Hamid and Stuart E. Madnick.
:END-OF-REPORT

:REPORT INFO7}
:TITLE Planning Subsystem
:LOCATION -1,-1
:SIZE 54,12

This diagram illustrates the planning subsystem of the model as a function of initial estimates which are revised through the life of the project. It illustrates a causal-loop structure of the adjustments to workforce and schedule.

This subsystem is one of four subsystems that comprise the software development and management model. The diagram depicts not only the information variables, but also their feedback flows and interrelationship with other sectors and subsystems.

A more detail description of the sector and related subsystems can be found in "Software Project Dynamics, An integrated Approach", by Tarek K. Abdel-Hamid and Stuart E. Madnick.
:END-OF-REPORT

:REPORT HELP1
:TITLE Post-Analysis Help
:LOCATION 30,75
:SIZE 52,20

In order to conduct post-analysis of games, the user must load a previously run game. Once it is loaded, the user can easily perform analysis of the output. The user will load in the previous games by clicking on the Load button. This action will display a Load and Reorder Previous Scenarios window, which displays the names of previously saved games.

The Load and reorder command will put up a window with two lists. On the left is a list of loaded scenarios and on the right is a list of scenarios that have been run.

The << button loads scenarios. Click on the scenario you want to load in the right hand list, and then click the << button. If you do not have a mouse available, use the TAB and Return (or Enter) key combination to move among the boxed selection items and to make your selection.

The >> button unloads scenarios. Click on the scenario you want to unload in the left hand list, and the click on the >> button. If the list on the right is empty, you will need to run some simulation scenarios. You can do that by exiting to the main menu and selecting to run a game.

You can load up to 8 scenarios at a time, but it is recommended that no more than four be loaded at any given time since it becomes difficult to read graphs with more than four scenarios loaded.

The Select option allows the user to select a variable of interest for analysis. A Variable Selection control window that contains a list of variable names in the current model will be displayed. The user can make his selection by double-clicking on any variable on the list, by clicking on the variable of interest and then clicking on the SELECT button, or by typing in the space provided the name of the variable and then clicking the SELECT button.

Causal tracing is a process that allows you to determine the underlying causes of model behavior, and the differences in behavior between different scenarios. There are four options available for doing causal tracing. They are:

1) The Tree option enables the display of causes of the variable of interest, as a tree that branches from the right. Variables that are shown between parenthesis indicate that they appear somewhere else in the tree. Also, this option displays a graphical representation of the variable of interest. An option menu is provided for the user to continue further analysis.

2) The graph option is a refinement of the Tree option. It allows the display of the equation for the variable of interest and other pertinent information, and the graphical display of a predetermined set of variable levels affecting the variable of interest. An option menu is provided for the user to continue further analysis.

3) The Uses option enables the display of a uses of a variable as a tree branching from the left. Variables that are shown between parenthesis indicate that they appear somewhere else in the tree. Also, this option displays a graphical representation of the variable of interest. An option menu is provided for the user to continue further analysis.

4) The Loop option displays a list of all feedback loops passing through the variable of interest. The list is ordered from the shortest loop (the one involving the least number of variables) to the longest loop. Loops provides useful information about model interactions. Also, this option provides useful information about the variable of interest. An option menu is provided for the user to continue further analysis.

The List Differences option allows comparison of the constants used in the first scenario run to those in the second loaded scenario in a table format.

The Help option will produce this dialog window when selected. It can be locked in place, printed, copied into the Windows clipboard, or deleted when no longer needed.

The Return to Option will place the user at the main menu of the simulation.

The Exit option will terminate the simulation and close the program.
:END-OF-REPORT

:REPORT HELP2
:TITLE Simulation Analysis Help
:LOCATION 30,75
:SIZE 52,22

You can perform analysis of games at any time during its execution.

The Select option allows the user to select a variable of interest for analysis. A variable Selection control window that contains a list of variable names in the current model will be displayed. The user can make his selection by double-clicking on any variable on the list, by clicking on the variable of interest and then clicking on the SELECT button, or by typing in the space provided the name of the variable and then clicking the SELECT button.

Causal tracing is a process that allows you to determine the underlying causes of model behavior, and the differences in behavior between different scenarios. There are four options available for doing causal tracing. They are:

1) The Tree option enables the display of causes of the variable of interest, as a tree that branches from the right. Variables that are shown between parenthesis indicate that they appear somewhere else in the tree. Also, this option displays a graphical representation of the variable of interest. An option menu is provided for the user to continue further analysis.

2) The graph option is a refinement of the Tree option. It allows the display of the equation for the variable of interest and other pertinent information, and the graphical display of a predetermined set of variable levels affecting the variable of interest. An option menu is provided for the user to continue further analysis.

3) The Uses option enables the display of the uses of a variable as a tree branching from the left. Variables that are shown between parenthesis indicate that they appear somewhere else in the tree. Also, this option displays a graphical representation of the variable of interest. An option menu is provided for the user to continue further analysis.

4) The Loop option displays a list of all feedback loops passing through the variable of interest.

The list is ordered from the shortest loop (the one involving the least number of variables) to the longest loop. Loops provides useful information about model interactions. Also, this option provides useful information about the variable of interest. An option menu is provided for the user to continue further analysis.

The Help option will produce this dialog window when selected. It can be locked in place, printed, copied into the Windows clipboard, or deleted when no longer needed.

The Exit to Simulation option, when selected, will place the user back to the game control center to continue playing the game.
:END-OF-REPORT

:REPORT HELP3
:TITLE Causal Tracing Help
:LOCATION 12,30
:SIZE 56,12

Causal tracing is a process that allows you to determine the underlying causes of model behavior, and the differences in behavior between different scenarios. Several screens provide several methods to study the causes of a variable of interest. The functions can be executed by pointing and clicking the respective buttons, or by pressing in the keyboard "ALT" and the first

letter of the word in the label indicated in the button. The following are options available for analysis:

1) The Trace on Highlight option allows the user to select a new variable of interest from the displayed tree diagram by clicking to highlight the desired new variable. Click on the "Yes" button to execute. The screen will automatically display the new variable of interest, its tree, and applicable graph. This function is executed also by pointing and double clicking the mouse left button on the variable of interest. This function is not available using the keyboard.

2) The Trace Loops option displays a list of all feedback loops passing through the variable of interest. The list is ordered from the shortest loop (the one involving the least number of variables) to the longest loop. Loops provides useful information about model interactions. Also, this option provides useful information about the variable of interest. An option menu is provided for the user to continue further analysis.

3) The Tree option enables the display of a causes of the variable of interest, as a tree that branches from the right. Variables that are shown between parenthesis indicate that they appear somewhere else in the tree. Also, this option displays a graphical representation of the variable of interest. An option menu is provided for the user to continue further analysis.

4) The Graph option is a refinement of the Tree option. It displays the equation containing the variable of interest and other pertinent information and the graphical display of a predetermined set of variable levels affecting the variable of interest. An option menu is provided for the user to continue further analysis.

5) The Uses option enables the display of the uses of a variable as a tree branching from the left. Variables that are shown between parenthesis indicate that they appear somewhere else in the tree. Also, this option displays a graphical representation of the variable of interest. An option menu is provided for the user to continue further analysis.

6) The Print options, depending of the options menu, will print the tree diagram, graph(s), loops involving the variable of interest, or the equation containing the variable of interest to the selected printer.

7) The Data Table option enables the display a window of the causes of the variable of interest in a tabulated table of values. This window can be locked in place, printed, copied into the Windows clipboard, or deleted when no longer needed.

8) The Select a New Variable function allows users to change the variable of interest among a given set of variables in the simulation. Users, using the trace on highlight option, can navigate and explore other variables within in the model. This option will let the user return back to the given set of variables to re-select among the given set after exploring other variables.

9) The Help option will produce this dialog window when selected. It can be locked in place, printed, copied into the Windows clipboard, or deleted when no longer needed.

10) The Exit to Simulation option, when selected, will place the user back to the game control center to continue playing the game.
:END-OF-REPORT

:REPORT EXP1
:TITLE Information
:LOCATION -1,-1
:SIZE 45,10

Project Cost: Enter your estimates for total Project Cost in Person-Days.
Project Duration: Enter your updated estimate for the Project Duration in days.
Staffing Level: Enter your total requested Staffing Level.
Pct Alloc to QA: Enter the desired percent of personnel allocated to Quality Assurance as a number from 0 to 100.
:END-OF-REPORT

:REPORT RPT1
:TITLE Staffing Report
:LOCATION -1,-1
:SIZE 35,8

```
At time = \TM/ days
 Current Total Staff Size                      \FTEQWF/  Persons
    Staff Allocated to Programming            \CRDVWF/  Persons
    Staff Allocated to QA                        \CRQAWF/  Persons
 Percent of Workforce that is Experienced    \FRWFEX PCT/  Percent
```

:END-OF-REPORT

:REPORT RPT2
:TITLE Project Status Report
:LOCATION -1,-1
:SIZE 45,14

```
At Time  =  \TM/ days
UPDATED ESTIMATES
    New Est of System Size due to changes in requirements     \PJBSZT/ DSI
    Your Last Est of Programming Phase Cost                       \JBSZMD/ Person-Days
    Your Last Est of Programming Phase Duration                    \SCHCDT/ Days
    Time Remaining                                                     \TIMERM/ Days
```

```
REPORTED PROGRESS
    Percent DSI Reported Complete                          \PRCMPL/ Percent
    Total DSI Reported Complete to Date                    \CMDSI/ DSI
    Total Person-Days Expended to Date                     \CUMMD/ Person-Days
    Reported Productivity                                  \RPPROD/
DSI/Person-Days
:END-OF-REPORT

:REPORT RPT3
:TITLE Defect Report
:LOCATION -1,-1
:SIZE 45,16

At Time = \TM/ days
CUMULATIVE  STATISTICS FROM START OF PROJECT
    TOTAL Person Days Expended to Date                     \CUMMD/ Person-Days
    Programming Person Days Expended to Date               \CUMMD TD/ Person-Days
    QA Person-Days Expended to Date                        \CMQAMD/ Person-Days

    TOTAL Defects Detected                                 \CMERD/ Defects
    TOTAL KDSI Completed                                   \CMDSI KDSI/ KDSI
    Defect Density                                         \CMERD KDSI/ Defects/KDSI

STATISTICS FOR THE LAST 40 DAY PERIOD ONLY
    QA Person Days Expended                                \PRQAMD/ Person-Days
    Defects Detected                                       \PRERD/ Defects
    Density of Defects Detected                            \PRDFDS/ Defects/KDSI
:END-OF-REPORT

:GRAPH STATUS_GRAPH1
:TITLE Project Size and Status Graph
:X-LABEL Time in Days
:X-MIN 0
:X-MAX 600
:SCALE
:VAR JBSZMD|Estimated Programming Cost
:LINE-WIDTH 2
:UNITS Person-Days
:Y-MIN 0
:Y-MAX 4000
:SCALE
:VAR PJBSZT KDSI|Estimated System Size
:LINE-WIDTH 2
:UNITS KDSI
:Y-MIN 0
:Y-MAX 64
:SCALE
:VAR FTEQWF|Total Staff
:LINE-WIDTH 2
```

:UNITS Persons
:Y-MIN 0
:Y-MAX 24

:GRAPH UNSTACKED_2A
:TITLE Estimated Programming Cost
:X-LABEL Time in Days
:X-MIN 0
:X-MAX 600
:SCALE
:VAR JBSZMD
:LINE-WIDTH 2
:UNITS Person-Days
:Y-MIN 0
:Y-MAX 4000

:GRAPH UNSTACKED_2B
:TITLE Estimated System Size
:X-LABEL Time in Days
:X-MIN 0
:X-MAX 600
:SCALE
:VAR PJBSZT KDSI
:LINE-WIDTH 2
:UNITS KDSI
:Y-MIN 0
:Y-MAX 64

:GRAPH UNSTACKED_2C
:TITLE Total Staffing Level
:X-LABEL Time in Days
:X-MIN 0
:X-MAX 600
:SCALE
:VAR FTEQWF
:LINE-WIDTH 2
:UNITS Persons
:Y-MIN 0
:Y-MAX 24

:GRAPH DEFECTS
:TITLE Total Defects
:X-LABEL Time in Days
:X-MIN 0
:X-MAX 600
:WIP
:SCALE
:VAR PRQAMD PERIOD|QA Person-Days per KDSI
:LINE-WIDTH 2

:Y-MIN 0
:Y-MAX 80
:VAR PRDFDS|Defects Detected per KDSI
:LINE-WIDTH 2
:Y-MIN 0
:Y-MAX 80

:GRAPH STAFFING_LEVEL
:TITLE Total Staff Composition
:X-LABEL Time in Days
:X-MIN 0
:X-MAX 600
:SCALE
:VAR FTEQWF|Total Staff
:LINE-WIDTH 2
:UNITS Persons
:Y-MIN 0
:Y-MAX 24
:VAR CRDVWF|Pgm Staff
:LINE-WIDTH 2
:UNITS Persons
:Y-MIN 0
:Y-MAX 24
:VAR CRQAWF|QA Staff
:LINE-WIDTH 2
:UNITS Persons
:Y-MIN 0
:Y-MAX 24

APPENDIX C.

SMFS CUSTOM DESCRIPTION (VCD) FILE

This appendix contains a listing of the SMFS Vensim application (Venapps). The scripts that follow make possible the use of the Causal.vmf model and Causal.vgd file to form an easy-to-use interface application that facilitates the use and the interpretation of results from the software development and management model. The listing provides a series of menus and sequence of screens that allow the user of the SMFS to use and analyze the software development and management model in a straightforward and meaningful way. These sequence of screens is stored in a .vcd file. The SMFS Venapps is controlled using the file Causal.vcd. This file defines the appearance and behavior of the application using a simple scripting language. The structure and syntax of a Venapp screen follows this convention: Name, Text, Position, Justification, Accelerator/Range, Command, Shift screen. An example is shown in Figure 27.

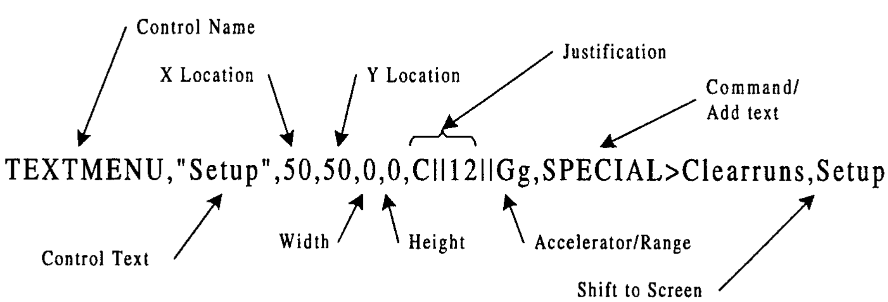

Figure 27. Venapps Screen Format [Ventana, 1994, p. 316]

Controls form the basic components in a Venapps application screen. There are four types of controls available in the Vensim scripting language. They are:

- Output - Places information on the screen
- Tool - Places the output of Vensim tools on the screen

- Input - Allows the user input to the screen
- Command - Determines the logical flow and transition between screens.

The contents in a Venapps screen are built up from a combination of the different controls available. The Venapps scripting language allows to draw objects and text, display variable values, change variables, and display the output of Vensim tools. Every screen created requires a name in order to be a valid reference in the .vcd file. In order to form a valid screen, the first line must begin with the keyword :SCREEN, followed by the screen name, as in :SCREEN Welcome. Following this statement, any valid command or control statement can be used to define the appearance and behavior of the screen. The following screens are contained in the Causal.vcd file.

:SCREEN WELCOME

```
SCREENFONT,Times New Roman|12||0-0-0|
COMMAND,"",0,0,0,0,,,SPECIAL>SETTITLE|"Software Management Flight Simulator"
COMMAND,"",0,0,0,0,,,SPECIAL>LOADMODEL|causal.vmf
COMMAND,"",0,0,0,0,,,SPECIAL>READCUSTOM|causal.vgd
COMMAND,"",0,0,0,0,,,SPECIAL>LOADTOOLSET|causal.vts
SKETCH,"Logo",5,15,90,65,,,1,
BUTTON,"Start",22,85,22,0,L,Rr,,CHOICES
BUTTON,"Exit",56,85,22,0,L,EeXx,SPECIAL>ASKYESNO|\
Do you want to exit the simulator?&MENU>EXIT,
```

:SCREEN CHOICES

```
SCREENFONT,Times New Roman|12||0-0-0
TEXTONLY,"Software Management Flight Simulator",0,15,100,0,C|Arial|22|B|255-25-0|,
LINE," ",10,30,80,0,C||||0-125-125,
TEXTONLY,"System Dynamics Primer",15,36,45,0,L|Arial|14|B|0-30-125|,
BUTTON,"System",60,36,20,0,L,Ss,,SYSTEM_DYNAMICS
TEXTONLY,"Simulator Model Overview",15,46,45,0,L|Arial|14|B|0-30-125|,
BUTTON,"Overview",60,46,20,0,L,Oo,,MODELS
TEXTONLY,"Play a New Game",15,56,45,0,L|Arial|14|B|0-30-125|,
BUTTON,"Game",60,56,20,0,L,Gg,,GAME_INTRO
TEXTONLY,"Analyze Previous Run Games",15,66,45,0,L|Arial|14|B|0-30-125|,
BUTTON,"Analyze",60,66,20,0,L,Aa,,POST_ANALYZE
TEXTONLY,"Exit Flight Simulator",15,76,45,0,L|Arial|14|B|0-30-125|,
BUTTON,"Exit",60,76,20,0,L,EeXx,SPECIAL>ASKYESNO|\
Do you want to exit the simulator?&MENU>EXIT,
LINE," ",10,87,80,0,C||||0-125-125,
```

:SCREEN SYSTEM_DYNAMICS

SKETCH,"System",0,0,100,90,,,10
BUTTON,"Return to Options",3,92,22,0,L,Rr,,CHOICES
BUTTON,"Primer",27,92,22,0,L,Pp,CUSTOM>SYSTEM
BUTTON,"Model Overview",51,92,22,0,L,Mm,,MODELS
BUTTON,"Exit",75,92,22,0,L,EeXx,SPECIAL>ASKYESNO|\Do you want to exit the simulator?&MENU>EXIT,

:SCREEN GAME_INTRO

TEXTONLY,"Game Instructions",0,5,100,0,C|Arial|20|B|255-25-0|,
TEXTONLY, "You are not allowed to discuss this exercise with anyone other than the lab attendant.",5,15,100,0,L
TEXTONLY, "Please refrain from discussing this with members in the other class until they have completed",5,20,100,0,L
TEXTONLY, "the exercise.",5,25,100,0,L
TEXTONLY, "",5,30,100,0,L
TEXTONLY, "The system will show you the size of the initial core team of software developers who have just",5,35,100,0,L
TEXTONLY, "completed the requirements/design specifications. The system will then advance to the",5,40,100,0,L
TEXTONLY, "programming phase where you will simulate the first 40 working day time period. You will",5,45,100,0,L
TEXTONLY, "be allowed to view the various reports, graphs, perform analysis, and then update your estimates",5,50,100,0,L
TEXTONLY, "for the project cost and duration and change your staffing levels.",5,55,100,0,L
TEXTONLY, "",5,60,100,0,L
TEXTONLY, "Record your decisions for each interval on the documentation sheet provided before",5,65,100,0,L
TEXTONLY, "proceeding to the next level.",5,70,100,0,L
TEXTONLY, "",5,75,100,0,L
TEXTONLY, "THE LAB ATTENDANT MUST VERIFY YOUR FINAL RESULTS. GOOD LUCK!",5,75,100,0,L|||B|255-0-0|,
BUTTON,"Continue",19,85,20,0,L,Cc,SIMULATE>RUNNAME|?NAME FOR NEW GAME OUTPUT (NOT BASE!!),STARTGAME
BUTTON,"Previous Menu",40,85,20,0,L,Pp,,CHOICES
BUTTON,"Exit",61,85,20,0,L,EeXx,SPECIAL>ASKYESNO|Do you want to exit the simulator?&MENU>EXIT,

:SCREEN STARTGAME

COMMAND,"",0,0,0,0,,,SPECIAL>CLEARRUNS
COMMAND,"",0,0,0,0,,,SIMULATE>BASED|
COMMAND,"",0,0,0,0,,,SIMULATE>RESUME|10
COMMAND,"",0,0,0,0,,,GAME>GAMEINTERVAL|40
COMMAND,"",0,0,0,0,,,MENU>GAME|O
COMMAND,"",0,0,0,0,,,SIMULATE>CHGFILE|
COMMAND,"",0,0,0,0,,,SIMULATE>BASED|
COMMAND,"",0,0,0,0,,,SIMULATE>RESUME|O
CLOSESCREEN,"",0,0,0,0,,,,INITIAL_ESTIMATE

:SCREEN INITIAL_ESTIMATE

```
TEXTONLY,"Initial Estimates",0,5,100,0,C|Arial|20|B|255-25-0|,
TEXTONLY,"The initial core team of software developers have just completed the requirements
and",11,15,100,0,L
TEXTONLY,"design specifications.  Your task is to take over as manager of the programming
phase.",7,20,100,0,L
TEXTONLY,"Shown below are the Initial Project Estimates:",7,25,0,0,L
TEXTONLY,"System Size in DSI",22,35,0,0,L||||0-0-125
SHOWVAR,"IPRJSZ",73,35,0,0,R||||0-0-125
TEXTONLY,"Cost of Programming Phase in Man-Days",22,40,0,0,L||||0-0-125
SHOWVAR,"TOTMD1INI",73,40,0,0,R||||0-0-125
TEXTONLY,"Duration of Programming Phase, days",22,45,0,0,L||||0-0-125
SHOWVAR,"TDEVINI",73,45,0,0,R||||0-0-125
TEXTONLY,"Initial Development Team, Men",22,50,0,0,L||||0-0-125
SHOWVAR,"WFS1",73,50,0,0,R||||0-0-125
TEXTONLY,"Pct of Staff Allocated to QA, (%Men)",22,55,0,0,L||||0-0-125
SHOWVAR,"FRMPQA",73,55,0,0,R||||0-0-125
TEXTONLY,"SMFS' estimate for the percent of the total staff to allocate to QA is shown
above.",11,65,100,0,L
TEXTONLY,"Remember, SMFS has not yet been calibrated to your environment.  This estimate
is",7,70,100,0,L
TEXTONLY,"merely illustrative.  It may or may not be appropriate for your unique project.  At
this",7,75,100,0,L
TEXTONLY,"point, you need to make two decisions based on this information.",7,80,100,0,L
TEXTONLY,"Press Any Key to Continue",0,90,100,0,C|Arial|14|B|0-0-125|,
ANYKEY,"",0,0,0,0,0,,,FIRST_DECISION
```

:SCREEN FIRST_DECISION

```
TEXTONLY,"Initial Programming Phase Decisions",0,4,100,0,C|Arial|20|B|255-25-0|,
TEXTONLY,"Initial Project Estimates",0,14,100,0,C||14|B|0-0-125|,
TEXTONLY,"System Size in DSI",22,20,0,0,L
SHOWVAR,"IPRJSZ",73,20,0,0,R
TEXTONLY,"Cost of Programming Phase in Man-Days",22,25,0,0,L
SHOWVAR,"TOTMD1INI",73,25,0,0,R
TEXTONLY,"Duration of Programming Phase, Days",22,30,0,0,L
SHOWVAR,"TDEVINI",73,30,0,0,R
TEXTONLY,"Initial Development Team, Men",22,35,0,0,L
SHOWVAR,"WFS1",73,35,0,0,R
TEXTONLY,"Pct of Staff Allocated to QA, (%Men)",22,40,0,0,L
SHOWVAR,"FRMPQA",73,40,0,0,R
TEXTONLY, "FIRST DECISION:  Determine the Total Staff Level for the Programming \
Phase.",0,48,100,0,C||12|B||
TEXTONLY,"Staffing Level",35,54,0,0,L|||B|0-0-125|
MODVAR,"WFS1",57,54,7,5,,[0|]
TEXTONLY, "SECOND DECISION:  Determine the % of Personnel Allocated to \
Quality Assurance.",0,62,100,0,C||12|B||
TEXTONLY,"Pct Alloc to QA",35,68,0,0,L|||B|0-0-125|
MODVAR,"FRMPQA",57,68,7,5,,[0|100]
TEXTONLY, "IMPORTANT!!",0,80,100,0,C|||B|255-0-0|,
```

```
TEXTONLY, "This is Your FINAL Opportunity to Change These Values.",0,84,100,0,C
BUTTON,"Advance Time",38,90,25,0,,Aa,GAME>GAMEON,CONTROL
```

:SCREEN CONTROL

```
TEXTONLY,"Control  Center",0,5,100,0,C|Arial|22|B|125-0-125
RECTANGLE,"",2,15,40,30
TEXTONLY,"INITIAL PROJECT ESTIMATES",4,16,0,0,L|||B|0-0-255
TEXTONLY,"System Size in DSI",3,23,0,0,L|Arial|10||
SHOWVAR,"IPRJSZ",34,23,7,3,R|Arial|10||
TEXTONLY,"Cost of Programming, Man-Days",3,28,0,0,L|Arial|10||
SHOWVAR,"TOTMD1",34,28,7,3,R|Arial|10||
TEXTONLY,"Duration of Programming, Days",3,33,0,0,L|Arial|10||
SHOWVAR,"TDEVINI",34,33,7,3,R|Arial|10||
TEXTONLY,"Initial Development Team, Men",3,38,0,0,L|Arial|10||
SHOWVAR,"WFSINI",34,38,7,3,R|Arial|10||
RECTANGLE,"",45,15,52,30
TEXTONLY,"CURRENT STATISTICS",58,16,0,0,L|||B|255-25-0
TEXTONLY,"New System Size in DSI",46,23,0,0,L|Arial|10||
SHOWVAR,"PJBSZT",87,23,7,3,R|Arial10|||
TEXTONLY,"Total DSI Reported Completed",46,28,0,0,L|Arial|10||
SHOWVAR,"CMDSI",87,28,7,3,R|Arial|10||
TEXTONLY,"Reported Productivity, DSI/Man-Days",46,33,0,0,L|Arial|10||
SHOWVAR,"RPPROD",87,33,7,3,R|Arial|10||
TEXTONLY,"Time in Days",46,38,0,0,L|Arial|10||
SHOWVAR,"TM",87,38,7,3,R|Arial|10||
RECTANGLE,"",2,47,40,40
TEXTONLY,"INPUT VARIABLES",11,48,0,0,L|||B|125-125-0
TEXTONLY,"Project Cost, Man-Days",3,55,0,0,L|Arial|10||
MODVAR,"TOTMD1",32,55,8,5,R,[0||999999]
TEXTONLY,"Project Duration, Days",3,61,0,0,L|Arial|10||
MODVAR,"PROJDR",32,61,8,5,R,[0||9999]
TEXTONLY,"Staffing Level, Men",3,67,0,0,L|Arial|10||
MODVAR,"WFS1",32,67,8,5,R,[0||999]
TEXTONLY,"Pct Alloc to QA, %Men",3,73,0,0,L|Arial|10||
MODVAR,"FRMPQA",32,73,8,5,R,[0|100|9999]
BUTTON,"Help",9,79,25,0,L,Hh,CUSTOM>EXP1
BUTTON,"Project Status Report",45,49,25,0,L,Pp,CUSTOM>RPT2
BUTTON,"P®oject Status Graphs",72,49,25,0,L,Rr,,PROJ_STATUS_GRAPH1
BUTTON,"Staffing Report",45,59,25,0,L,Ss,CUSTOM>RPT1
BUTTON,"S(t)affing Graph",72,59,25,0,L,Tt,,STAFFING_GRAPH
BUTTON,"Defect Report",45,69,25,0,L,Dd,CUSTOM>RPT3
BUTTON,"De(f)ect Graph",72,69,25,0,L,Ff,,DEFECT_GRAPH
BUTTON,"A(n)alyze Scenario",45,79,25,0,L,Nn,,SIM_ANALYZE
BUTTON,"End Simulation",72,79,25,0,L,EeXx,SPECIAL>ASKYESNO|Do you want to end
this simulation?\&GAME>ENDGAME,WELCOME
BUTTON,"Advance Time",38,91,25,0,L,Aa,GAME>GAMEON&BRANCH>TRANSIT
BRANCH,"TRANSIT",0,0,0,0,,,IFTHENELSE&TEST>PJBAWK<=.995&BRANCH>CONTIN
UE&BRANCH>END
BRANCH,"CONTINUE",0,0,0,0,,,,CONTROL
```

```
BRANCH,"END",0,0,0,0,,,GAME>ENDGAME
```

:SCREEN PROJ_STATUS_GRAPH1

```
TOOL,"GR1",0,0,100,90,,,CUSTOM>STATUS_GRAPH1
BUTTON,"Go Back",5,93,25,0,L,Gg,,CONTROL
BUTTON,"Unstack Graphs",37,93,25,0,L,Uu,,UNSTACKED_MENU
BUTTON,"Print Current View",70,93,25,0,L,Pp,PRINT>GR1
```

:SCREEN UNSTACKED_MENU

```
TEXTONLY,"Listed below are the three individual graphs which are plotted on the",0,70,100,0,C||14||255-0-0|,
TEXTONLY,"Project Status Graph.  Select the desired graph or table of numeric values.",0,75,100,0,C||14||255-0-0|,
TOOL,"GR1",0,0,100,65,,,CUSTOM>STATUS_GRAPH1
BUTTON,"Pgm ©ost Graph",2,86,20,0,L,Cc,,UNSTACKED_PGM_COST
BUTTON,"Pg(m) Cost Table",2,93,20,0,L,Mm,,PGM_COST_TABLE
BUTTON,"Sys Size Graph",27,86,20,0,L,Ss,,UNSTACKED_SYS_SIZE
BUTTON,"S(y)s Size Table",27,93,20,0,L,Yy,,SYS_SIZE_TABLE
BUTTON,"S(t)affing Graph",52,86,20,0,L,Tt,,UNSTACKED_TOT_STAFF
BUTTON,"St(a)ffing Table",52,93,20,0,L,Aa,,TOT_STAFF_TABLE
BUTTON,"Go Back",78,86,20,0,L,Gg,,PROJ_STATUS_GRAPH1
BUTTON,"Print Current View",78,93,20,0,L,Pp,PRINT>GR1
```

:SCREEN UNSTACKED_PGM_COST

```
TOOL,"GR1A1",0,0,100,80,,,CUSTOM>UNSTACKED_2A
BUTTON,"Pgm ©ost Graph",2,86,20,0,L,Cc,,UNSTACKED_PGM_COST
BUTTON,"Pg(m) Cost Table",2,93,20,0,L,Mm,,PGM_COST_TABLE
BUTTON,"Sys Size Graph",27,86,20,0,L,Ss,,UNSTACKED_SYS_SIZE
BUTTON,"S(y)s Size Table",27,93,20,0,L,Yy,,SYS_SIZE_TABLE
BUTTON,"S(t)affing Graph",52,86,20,0,L,Tt,,UNSTACKED_TOT_STAFF
BUTTON,"St(a)ffing Table",52,93,20,0,L,Aa,,TOT_STAFF_TABLE
BUTTON,"Go Back",78,86,20,0,L,Gg,,PROJ_STATUS_GRAPH1
BUTTON,"Print Current View",78,93,20,0,L,Pp,PRINT>GR1A1
```

:SCREEN PGM_COST_TABLE

```
TEXTONLY,"Estimated Programming Cost",0,5,100,0,C|Times New Roman|16|
COMMAND,"",0,0,0,0,,,SPECIAL>SETWBITEM|JBSZMD
TOOL,"GR1A2",0,30,100,40,,,WORKBENCH>CAUSES TAB
BUTTON,"Pgm ©ost Graph",2,86,20,0,L,Cc,,UNSTACKED_PGM_COST
BUTTON,"Pg(m) Cost Table",2,93,20,0,L,Mm,,PGM_COST_TABLE
BUTTON,"Sys Size Graph",27,86,20,0,L,Ss,,UNSTACKED_SYS_SIZE
BUTTON,"S(y)s Size Table",27,93,20,0,L,Yy,,SYS_SIZE_TABLE
BUTTON,"S(t)affing Graph",52,86,20,0,L,Tt,,UNSTACKED_TOT_STAFF
BUTTON,"St(a)ffing Table",52,93,20,0,L,Aa,,TOT_STAFF_TABLE
BUTTON,"Go Back",78,86,20,0,L,Gg,,PROJ_STATUS_GRAPH1
BUTTON,"Print Current View",78,93,20,0,L,Pp,PRINT>GR1A2
```

:SCREEN UNSTACKED_SYS_SIZE

```
TOOL,"GR2A1",0,0,100,80,,,CUSTOM>UNSTACKED_2B
```

```
BUTTON,"Pgm ©ost Graph",2,86,20,0,L,Cc,,UNSTACKED_PGM_COST
BUTTON,"Pg(m) Cost Table",2,93,20,0,L,Mm,,PGM_COST_TABLE
BUTTON,"Sys Size Graph",27,86,20,0,L,Ss,,UNSTACKED_SYS_SIZE
BUTTON,"S(y)s Size Table",27,93,20,0,L,Yy,,SYS_SIZE_TABLE
BUTTON,"S(t)affing Graph",52,86,20,0,L,Tt,,UNSTACKED_TOT_STAFF
BUTTON,"St(a)ffing Table",52,93,20,0,L,Aa,,TOT_STAFF_TABLE
BUTTON,"Go Back",78,86,20,0,L,Gg,,PROJ_STATUS_GRAPH1
BUTTON,"Print Current View",78,93,20,0,L,Pp,PRINT>GR2A1
```

:SCREEN SYS_SIZE_TABLE

```
TEXTONLY,"Estimated System Size",0,5,100,0,C|Times New Roman|16|
COMMAND,"",0,0,0,0,,,SPECIAL>SETWBITEM|PJBSZT KDSI
TOOL,"GR2A2",0,30,100,40,,,WORKBENCH>CAUSES TAB
BUTTON,"Pgm ©ost Graph",2,86,20,0,L,Cc,,UNSTACKED_PGM_COST
BUTTON,"Pg(m) Cost Table",2,93,20,0,L,Mm,,PGM_COST_TABLE
BUTTON,"Sys Size Graph",27,86,20,0,L,Ss,,UNSTACKED_SYS_SIZE
BUTTON,"S(y)s Size Table",27,93,20,0,L,Yy,,SYS_SIZE_TABLE
BUTTON,"S(t)affing Graph",52,86,20,0,L,Tt,,UNSTACKED_TOT_STAFF
BUTTON,"St(a)ffing Table",52,93,20,0,L,Aa,,TOT_STAFF_TABLE
BUTTON,"Go Back",78,86,20,0,L,Gg,,PROJ_STATUS_GRAPH1
BUTTON,"Print Current View",78,93,20,0,L,Pp,PRINT>GR2A2
```

:SCREEN UNSTACKED_TOT_STAFF

```
TOOL,"GR3A1",0,0,100,80,,,CUSTOM>UNSTACKED_2C
BUTTON,"Pgm ©ost Graph",2,86,20,0,L,Cc,,UNSTACKED_PGM_COST
BUTTON,"Pg(m) Cost Table",2,93,20,0,L,Mm,,PGM_COST_TABLE
BUTTON,"Sys Size Graph",27,86,20,0,L,Ss,,UNSTACKED_SYS_SIZE
BUTTON,"S(y)s Size Table",27,93,20,0,L,Yy,,SYS_SIZE_TABLE
BUTTON,"S(t)affing Graph",52,86,20,0,L,Tt,,UNSTACKED_TOT_STAFF
BUTTON,"St(a)ffing Table",52,93,20,0,L,Aa,,TOT_STAFF_TABLE
BUTTON,"Go Back",78,86,20,0,L,Gg,,PROJ_STATUS_GRAPH1
BUTTON,"Print Current View",78,93,20,0,L,Pp,PRINT>GR3A1
```

:SCREEN TOT_STAFF_TABLE

```
TEXTONLY,"Total Staffing Level",0,5,100,0,C|Times New Roman|16|
COMMAND,"",0,0,0,0,,,SPECIAL>SETWBITEM|FTEQWF
TOOL,"GR3A2",0,30,100,40,,,WORKBENCH>CAUSES TAB
BUTTON,"Pgm ©ost Graph",2,86,20,0,L,Cc,,UNSTACKED_PGM_COST
BUTTON,"Pg(m) Cost Table",2,93,20,0,L,Mm,,PGM_COST_TABLE
BUTTON,"Sys Size Graph",27,86,20,0,L,Ss,,UNSTACKED_SYS_SIZE
BUTTON,"S(y)s Size Table",27,93,20,0,L,Yy,,SYS_SIZE_TABLE
BUTTON,"S(t)affing Graph",52,86,20,0,L,Tt,,UNSTACKED_TOT_STAFF
BUTTON,"St(a)ffing Table",52,93,20,0,L,Aa,,TOT_STAFF_TABLE
BUTTON,"Go Back",78,86,20,0,L,Gg,,PROJ_STATUS_GRAPH1
BUTTON,"Print Current View",78,93,20,0,L,Pp,PRINT>GR3A2
```

:SCREEN DEFECT_GRAPH

```
TOOL,"DR1",0,0,100,90,,,CUSTOM>DEFECTS
BUTTON,"Go Back",5,93,25,0,L,Gg,,CONTROL
```

```
BUTTON,"View Table",37,93,25,0,L,Vv,,DEFECT_TABLE
BUTTON,"Print Current View",70,93,25,0,L,Pp,PRINT>DR1

:SCREEN DEFECT_TABLE
TEXTONLY,"Total Defects",0,5,100,0,C|Times New Roman|16|
COMMAND,"",0,0,0,0,,,SPECIAL>SETWBITEM|PRQAMD PERIOD
TOOL,"GR4",0,30,100,40,,,WORKBENCH>CAUSES TAB
COMMAND,"",0,0,0,0,,,SPECIAL>SETWBITEM|PRDFDS
TOOL,"GR4",0,70,100,40,,,WORKBENCH>CAUSES TAB
BUTTON,"Go Back",17,93,25,0,L,Gg,,DEFECT_GRAPH
BUTTON,"Print Current View",60,93,25,0,L,Pp,PRINT>GR4

:SCREEN STAFFING_GRAPH
TOOL,"SG1",0,0,100,90,,,CUSTOM>STAFFING_LEVEL
BUTTON,"Go Back",5,93,25,0,L,Gg,,CONTROL
BUTTON,"View Table",37,93,25,0,L,Vv,,STAFFING_TABLE
BUTTON,"Print Current View",70,93,25,0,L,Pp,PRINT>SG1

:SCREEN STAFFING_TABLE
TEXTONLY,"Total Staff Composition",0,5,100,0,C|Times New Roman|16|
COMMAND,"",0,0,0,0,,,SPECIAL>SETWBITEM|FTEQWF
TOOL,"GR5",0,20,100,40,,,WORKBENCH>CAUSES TAB
COMMAND,"",0,0,0,0,,,SPECIAL>SETWBITEM|CRQAWF
TOOL,"GR5",0,55,100,40,,,WORKBENCH>CAUSES TAB
COMMAND,"",0,0,0,0,,,SPECIAL>SETWBITEM|CRDVWF
TOOL,"GR5",0,85,100,30,,,WORKBENCH>CAUSES TAB
BUTTON,"Go Back",17,93,25,0,L,Gg,,STAFFING_GRAPH
BUTTON,"Print Current View",60,93,25,0,L,Pp,PRINT>GR5

:SCREEN MODELS
TEXTONLY,"Simulator Model Structures",28,5,45,0,C|Arial|26|B|255-0-0|,
TEXTONLY,"Model Overview",10,20,45,0,L|Arial|14|B|0-125-0|,
BUTTON,"Overview",68,20,20,0,L,Oo,,OVERVIEW
TEXTONLY,"Human Resources Subsystem",10,28,45,0,L|Arial|14|B|0-30-125|,
BUTTON,"HR",68,28,20,0,L,Hh,,HUMAN_RESOURCES_OV
TEXTONLY,"Manpower Allocation Sector",10,36,0,0,L|Arial|14|B|0-30-125|,
BUTTON,"Manpower",68,36,20,0,L,Mm,,MAN_POWER_OV
TEXTONLY,"SW Development Productivity Subsector",10,44,45,0,L|Arial|14|B|0-30-125|,
BUTTON,"Software",68,44,20,0,L,Ss,,SW_DEV_PROD_OV
TEXTONLY,"Quality Assurance Sector",10,52,45,0,L|Arial|14|B|0-30-125|,
BUTTON,"QA",68,52,20,0,L,Qq,,QUALITY_ASSURANCE_OV
TEXTONLY,"System Testing Sector",10,60,45,0,L|Arial|14|B|0-30-125|,
BUTTON,"Testing",68,60,20,0,L,Tt,,SYS_TESTING_OV
TEXTONLY,"Controlling Subsystem",10,68,45,0,L|Arial|14|B|0-30-125|,
BUTTON,"Control",68,68,20,0,L,Cc,,CONTROL_SYS_OV
TEXTONLY,"Planning Subsystem",10,76,45,0,L|Arial|14|B|0-30-125|,
BUTTON,"Planning",68,76,20,0,L,Pp,,PLANNING_SYS_OV
BUTTON,"Return to Options",28,90,20,0,L,Rr,,CHOICES
BUTTON,"Exit",52,90,20,0,L,EeXx,SPECIAL>ASKYESNO|\
```

```
Do you want to exit the simulator?&MENU>EXIT,

:SCREEN OVERVIEW
TEXTONLY,"Simulator Main Block Components",0,5,100,0,C|128|B|255-0-0,0
SKETCH,"SK1",10,15,80,75,,,2
BUTTON,"Info",2,92,11,0,L,Ii,CUSTOM>INFO
BUTTON,"Print View",15,92,22,0,L,Pp,PRINT>SK1
BUTTON,"Model Components",39,92,22,0,L,Mm,,MODELS
BUTTON,"Return to Options",63,92,22,0,L,Rr,,CHOICES
BUTTON,"Exit",87,92,11,0,L,EeXx,SPECIAL>ASKYESNO|\
Do you want to exit the simulator?&MENU>EXIT,

:SCREEN HUMAN_RESOURCES_OV
SKETCH,"SK2",0,0,100,90,,,3
BUTTON,"Info",2,92,11,0,L,Ii,CUSTOM>INFO1
BUTTON,"Print View",15,92,22,0,L,Pp,PRINT>SK2
BUTTON,"Model Components",39,92,22,0,L,Mm,,MODELS
BUTTON,"Return to Options",63,92,22,0,L,Rr,,CHOICES
BUTTON,"Exit",87,92,11,0,L,EeXx,SPECIAL>ASKYESNO|\
Do you want to exit the simulator?&MENU>EXIT,

:SCREEN MAN_POWER_OV
SKETCH,"SK3",0,0,100,90,,,4
BUTTON,"Info",2,92,11,0,L,Ii,CUSTOM>INFO2
BUTTON,"Print View",15,92,22,0,L,Pp,PRINT>SK3
BUTTON,"Model Components",39,92,22,0,L,Mm,,MODELS
BUTTON,"Return to Options",63,92,22,0,L,Rr,,CHOICES
BUTTON,"Exit",87,92,11,0,L,EeXx,SPECIAL>ASKYESNO|\
Do you want to exit the simulator?&MENU>EXIT,

:SCREEN SW_DEV_PROD_OV
SKETCH,"SK4",0,0,100,90,,,5
BUTTON,"Info",2,92,11,0,L,Ii,CUSTOM>INFO3
BUTTON,"Print View",15,92,22,0,L,Pp,PRINT>SK4
BUTTON,"Model Components",39,92,22,0,L,Mm,,MODELS
BUTTON,"Return to Options",63,92,22,0,L,Rr,,CHOICES
BUTTON,"Exit",87,92,11,0,L,EeXx,SPECIAL>ASKYESNO|\Do you want to exit the
simulator?&MENU>EXIT,

:SCREEN QUALITY_ASSURANCE_OV
SKETCH,"SK5",0,0,100,90,,,6
BUTTON,"Info",2,92,11,0,L,Ii,CUSTOM>INFO4
BUTTON,"Print View",15,92,22,0,L,Pp,PRINT>SK5
BUTTON,"Model Components",39,92,22,0,L,Mm,,MODELS
BUTTON,"Return to Options",63,92,22,0,L,Rr,,CHOICES
BUTTON,"Exit",87,92,11,0,L,EeXx,SPECIAL>ASKYESNO|\
Do you want to exit the simulator?&MENU>EXIT,
```

:SCREEN SYS_TESTING_OV

```
SKETCH,”SK6”,0,0,100,90,,,7
BUTTON,”Info”,2,92,11,0,L,Ii,CUSTOM>INFO5
BUTTON,”Print View”,15,92,22,0,L,Pp,PRINT>SK6
BUTTON,”Model Components”,39,92,22,0,L,Mm,,MODELS
BUTTON,”Return to Options”,63,92,22,0,L,Rr,,CHOICES
BUTTON,”Exit”,87,92,11,0,L,EeXx,SPECIAL>ASKYESNO|\
Do you want to exit the simulator?&MENU>EXIT,
```

:SCREEN CONTROL_SYS_OV

```
SKETCH,”SK7”,0,0,100,90,,,8
BUTTON,”Info”,2,92,11,0,L,Ii,CUSTOM>INFO6
BUTTON,”Print View”,15,92,22,0,L,Pp,PRINT>SK7
BUTTON,”Model Components”,39,92,22,0,L,Mm,,MODELS
BUTTON,”Return to Options”,63,92,22,0,L,Rr,,CHOICES
BUTTON,”Exit”,87,92,11,0,L,EeXx,SPECIAL>ASKYESNO|\
Do you want to exit the simulator?&MENU>EXIT,
```

:SCREEN PLANNING_SYS_OV

```
SKETCH,”SK8”,0,0,100,90,,,9
BUTTON,”Info”,2,92,11,0,L,Ii,CUSTOM>INFO7
BUTTON,”Print View”,15,92,22,0,L,Pp,PRINT>SK8
BUTTON,”Model Components”,39,92,22,0,L,Mm,,MODELS
BUTTON,”Return to Options”,63,92,22,0,L,Rr,,CHOICES
BUTTON,”Exit”,87,92,11,0,L,EeXx,SPECIAL>ASKYESNO|\
Do you want to exit the simulator?&MENU>EXIT,
```

:SCREEN POST_ANALYZE

```
TEXTONLY,”SIMULATION POST-ANALYSIS”,0,6,100,0,C|Arial|20|B|255-0-0|,
SETWB,” “,0,0,0,0,,,SPECIAL>SETWBITEM|PRDPRD
TEXTONLY,”Load, Unload,and Reorder Previously Run Scenarios”,30,20,0,0,L|Arial|12|B|\
0-0-125|,
BUTTON,”Load”,5,20,20,0,L,Ll,MENU>LOAD_RUN,
TEXTONLY,”Select Variable as a Start Point for Further Analysis”,30,30,0,0,L|Arial|12|B|\
0-0-125|,
BUTTON,”Select”,5,30,20,0,L,Ss,SPECIAL>SETWBITEM|PRDPRD\
&SPECIAL>VARSELECT|Select a New Variable to Trace,
TEXTONLY,”Trace Underlying Causes Using Trees”,30,40,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Trees”,5,40,20,0,L,Tt,,POST_CAUSE1
TEXTONLY,”Trace Underlying Causes Using Graphs”,30,50,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Graphs”,5,50,20,0,L,Gg,,POST_CAUSE2
TEXTONLY,”Trace the Uses of a Variable”,30,60,0,0,L|Arial|12|B|0-0-125
BUTTON,”Uses”,5,60,20,0,L,Uu,,POST_USE
TEXTONLY,”Trace the Feedback Loops of a Variable”,30,70,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Feedback”,5,70,20,0,L,Ff,,POST_LOOPS
TEXTONLY,”List Differences of First Two Loaded Scenarios”,30,80,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Differences”,5,80,20,0,L,Dd,,POST_DIFF
BUTTON,”Help”,10,90,25,0,L,Hh,CUSTOM>HELP1
BUTTON,”Return to Options”,37,90,25,0,L,Rr,SPECIAL>SETWBITEM|PRDPRD,CHOICES
```

```
BUTTON,"Exit",64,90,25,0,L,EeXx,SPECIAL>ASKYESNO|\
Do you want to exit the simulator?&SPECIAL>SETWBITEM|PRDPRD&MENU>EXIT,
```

:SCREEN POST_CAUSE1

```
TEXTONLY,"TREE CAUSAL TRACING -",20,2,0,0,L||16|B|255-0-0|,
WBVAR,"",62,2,0,0,L|Arial|16|B|0-125-125|,
TOOL,"TR1",2,7,96,42,,,WORKBENCH>CAUSES TREE
TEXTONLY,"OPTIONS",22,50,0,0,L|Arial|16|B|255-0-0|,
TEXTONLY,"Trace on Highlight",3,56,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Yes",43,56,10,5,L|Arial|10|B|,Yy,SPECIAL>SECONDCLICK|TR1,
TEXTONLY,"Trace Loops",3,62,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Loops",43,62,10,5,L|Arial|10|B|,Ll,,POST_LOOPS
TEXTONLY,"Change to Graph Based",3,68,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Graph",43,68,10,5,L|Arial|10|B|,Gg,,POST_CAUSE2
TEXTONLY,"Print Tree",3,74,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Print",16,74,10,5,L|Arial|10|B|,Pp,PRINT>TR1,
TEXTONLY,"Print Graph",28,74,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"OK",43,74,10,5,L|Arial|10|B|,Oo,PRINT>GR1
TEXTONLY,"Data Table",3,80,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Data",43,80,10,5,L|Arial|10|B|,Dd,WORKBENCH>CAUSES TAB
TEXTONLY,"Select a New Variable to Trace",3,86,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Select",43,86,10,5,L|AriaL|10|B|,Ss,SPECIAL>VARSELECT|New Variable for\
Tracing
TOOL,"GR1",55,50,43,49,,,WORKBENCH>STRIP GRAPH
BUTTON,"Help",5,93,20,5,I|Arial|10|B|,Hh,CUSTOM>HELP3
BUTTON,"Exit to Analysis",30,93,20,5,I|Arial|10|B|,eExX,SPECIAL>SETWBITEM|PRDPRD,\
POST_ANALYZE
SETWB,"",0,0,0,0,,,,POST_CAUSE1
```

:SCREEN POST_CAUSE2

```
TEXTONLY,"GRAPH CAUSAL TRACING -",1,2,50,0,L|||B|255-0-0
WBVAR,"",35,2,0,0,L|Arial|12|B|0-125-125|,
TEXTONLY,"OPTIONS",21,50,0,0,L|Arial|16|B|255-0-0|,
TEXTONLY,"Trace on Highlight",3,56,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Yes",43,56,10,5,L|Arial|10|B|,Yy,SPECIAL>SECONDCLICK|TR1,
TEXTONLY,"Trace Loops",3,62,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Loops",43,62,10,5,L|Arial|10|B|,Ll,,POST_LOOPS
TEXTONLY,"Change to Tree Based",3,68,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Tree",43,68,10,5,L|Arial|10|B|,Tt,,POST_CAUSE1
TEXTONLY,"Print Graph",3,74,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Print",18,74,10,5,L|Arial|10|B|,Pp,PRINT>TR1,
TEXTONLY,"Print Eqn",30,74,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"OK",43,74,10,5,L|Arial|10|B|,Oo,PRINT>GR1
TEXTONLY,"Data Table",3,80,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Data",43,80,10,5,L|Arial|10|B|,Dd,WORKBENCH>CAUSES TAB
TEXTONLY,"Select a New Variable to Trace",3,86,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Select",43,86,10,5,L|AriaL|10|B|,Ss,SPECIAL>VARSELECT|New Variable for\
Tracing
TOOL,"TR1",55,1,44,98,,,WORKBENCH>CAUSES STRIP
```

```
TOOL,"GR1",1,8,53,40,,,WORKBENCH>DOCUMENT
BUTTON,"Help",5,93,20,5,I|Arial|10|B|,Hh,CUSTOM>HELP3
BUTTON,"Exit to Analysis",30,93,20,5,I|Arial|10|B|,EeXx,SPECIAL>SETWBITEM|PRDPRD,\
POST_ANALYZE
SETWB,"",0,0,0,0,,,,POST_CAUSE2
```

:SCREEN POST_USE

```
TEXTONLY,"USES of -",36,2,0,0,L||16|B|255-0-0|,
WBVAR,"",51,2,0,0,L|Arial|16|B|0-125-125|,
TEXTONLY,"OPTIONS",21,50,0,0,L|Arial|16|B|255-0-0|,
TEXTONLY,"Trace on Highlight",3,56,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Yes",43,56,10,5,L|Arial|10|B|,Yy,SPECIAL>SECONDCLICK|TR1,
TEXTONLY,"Trace Loops",3,62,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Loops",43,62,10,5,L|Arial|10|B|,Ll,,POST_LOOPS
TEXTONLY,"Change to Tree Based",3,68,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Tree",43,68,10,5,L|Arial|10|B|,Tt,,POST_CAUSE1
TEXTONLY,"Change to Graph Based",3,74,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Graph",43,74,10,5,L|Arial|10|B|,Gg,,POST_CAUSE2
TEXTONLY,"Print Tree",3,80,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Print",16,80,10,5,L|Arial|10|B|,Pp,PRINT>TR1,
TEXTONLY,"Print Graph",28,80,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"OK",43,80,10,5,L|Arial|10|B|,Oo,PRINT>GR1
TEXTONLY,"Select a New Variable to Trace",3,86,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Select",43,86,10,5,L|AriaL|10|B|,Ss,SPECIAL>VARSELECT|New Variable for\
Tracing
TOOL,"TR1",2,7,96,42,,,WORKBENCH>USES TREE
TOOL,"GR1",55,50,43,49,,,WORKBENCH>STRIP GRAPH
BUTTON,"Help",5,93,20,5,I|Arial|10|B|,Hh,CUSTOM>HELP3
BUTTON,"Exit to Analysis",30,93,20,5,I|Arial|10|B|,EeXx,SPECIAL>SETWBITEM|PRDPRD,\
POST_ANALYZE
SETWB,"",0,0,0,0,,,,POST_USE
```

:SCREEN POST_LOOPS

```
TEXTONLY,"LOOPS CAUSAL TRACING -",1,2,50,0,L|||B|255-0-0
WBVAR,"",35,2,0,0,L|Arial|12|B|0-125-125|,
TEXTONLY,"OPTIONS",21,50,0,0,L|Arial|16|B|255-0-0|,
TEXTONLY,"Trace on Highlight",3,56,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Yes",43,56,10,5,L|Arial|10|B|,Yy,SPECIAL>SECONDCLICK|TR1,
TEXTONLY,"Change to Tree Based",3,62,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Tree",43,62,10,5,L|Arial|10|B|,Tt,,POST_CAUSE1
TEXTONLY,"Change to Graph Based",3,68,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Graph",43,68,10,5,L|Arial|10|B|,Gg,,POST_CAUSE2
TEXTONLY,"Print Loops",3,74,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Print",18,74,10,5,L|Arial|10|B|,Pp,PRINT>TR1,
TEXTONLY,"Print Eqn",30,74,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"OK",43,74,10,5,L|Arial|10|B|,Oo,PRINT>GR1
TEXTONLY,"Find Variable Uses",3,80,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Uses",43,80,10,5,L|Arial|10|B|,Us,,POST_USE
TEXTONLY,"Select a New Variable to Trace",3,86,0,0,L|Arial|12|B|0-0-125|,
```

BUTTON,”Select”,43,86,10,5,L|AriaL|10|B|,Ss,SPECIAL>VARSELECT|New Variable for\
Tracing
TOOL,”TR1”,55,1,44,98,,,WORKBENCH>LOOPS
TOOL,”GR1”,1,8,53,40,,,WORKBENCH>DOCUMENT
BUTTON,”Help”,5,93,20,5,||Arial|10|B|,Hh,CUSTOM>HELP3
BUTTON,”Exit to Analysis”,30,93,20,5,||Arial|10|B|,EeXx,SPECIAL>SETWBITEM|PRDPRD,\
POST_ANALYZE
SETWB,””,0,0,0,0,,,,POST_LOOPS

:SCREEN POST_DIFF
TEXTONLY,”Differences Between First Two Loaded Scenarios”\
,0,5,100,0,C|Arial|20|B|255-0-0|,
TOOL,”T1”,5,15,90,70,,,WORKBENCH>RUNS COMPARE
BUTTON,”Exit to Analysis”,20,90,25,0,L,EeXx,,POST_ANALYZE,
BUTTON,”Print”,55,90,25,0,L,Pp,PRINT>T1,POST_ANALYZE,

:SCREEN SIM_ANALYZE
TEXTONLY,”SIMULATION ANALYSIS”,0,6,100,0,C|Arial|20|B|255-0-0|,
SETWB,” “,0,0,0,0,,,SPECIAL>SETWBITEM|PRDPRD
TEXTONLY,”Select Variable as a Start Point for Further Analysis”,30,20,0,0,L|Arial|12|B|\
0-0-125|,
BUTTON,”Select”,5,20,20,0,L,Ss,,VARIABLES
TEXTONLY,”Trace Underlying Causes Using Trees”,30,30,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Trees”,5,30,20,0,L,Tt,,SIM_CAUSE1
TEXTONLY,”Trace Underlying Causes Using Graphs”,30,40,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Graphs”,5,40,20,0,L,Gg,,SIM_CAUSE2
TEXTONLY,”Trace the Uses of a Variable”,30,50,0,0,L|Arial|12|B|0-0-125
BUTTON,”Uses”,5,50,20,0,L,Uu,,SIM_USE
TEXTONLY,”Trace the Feedback Loops of a Variable”,30,60,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Loops”,5,60,20,0,L,Ff,,SIM_LOOPS
BUTTON,”Help”,22,80,25,0,L,Hh,CUSTOM>HELP2
BUTTON,”Exit to Simulation”,53,80,25,0,L,EeXx,SPECIAL>SETWBITEM|PRDPRD,\
CONTROL

:SCREEN SIM_CAUSE1
TEXTONLY,”TREE CAUSAL TRACING -“,20,2,0,0,L||16|B|255-0-0|,
WBVAR,””,62,2,0,0,L|Arial|16|B|0-125-125|,
TOOL,”TR1”,2,7,96,42,,,WORKBENCH>CAUSES TREE
TEXTONLY,”OPTIONS”,22,50,0,0,L|Arial|16|B|255-0-0|,
TEXTONLY,”Trace on Highlight”,3,56,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Yes”,43,56,10,5,L|Arial|10|B|,Yy,SPECIAL>SECONDCLICK|TR1,
TEXTONLY,”Trace Loops”,3,62,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Loops”,43,62,10,5,L|Arial|10|B|,Ll,,SIM_LOOPS
TEXTONLY,”Change to Graph Based”,3,68,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Graph”,43,68,10,5,L|Arial|10|B|,Gg,,SIM_CAUSE2
TEXTONLY,”Print Tree”,3,74,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Print”,16,74,10,5,L|Arial|10|B|,Pp,PRINT>TR1,
TEXTONLY,”Print Graph”,28,74,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”OK”,43,74,10,5,L|Arial|10|B|,Oo,PRINT>GR1

TEXTONLY,"Data Table",3,80,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Data",43,80,10,5,L|Arial|10|B|,Dd,WORKBENCH>CAUSES TAB
TEXTONLY,"Select a New Variable to Trace",3,86,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Select",43,86,10,5,L|AriaL|10|B|,Ss,,VARIABLES_1
TOOL,"GR1",55,50,43,49,,,WORKBENCH>STRIP GRAPH
BUTTON,"Help",5,93,20,5,||Arial|10|B|,Hh,CUSTOM>HELP3
BUTTON,"Exit to
Simulation",30,93,20,5,||Arial|10|B|,EeXx,SPECIAL>SETWBITEM|PRDPRD,\
CONTROL
SETWB,"",0,0,0,0,,,,SIM_CAUSE1

:SCREEN SIM_CAUSE2
TEXTONLY,"GRAPH CAUSAL TRACING -",1,2,50,0,L|||B|255-0-0
WBVAR,"",35,2,0,0,L|Arial|12|B|0-125-125|,
TEXTONLY,"OPTIONS",21,50,0,0,L|Arial|16|B|255-0-0|,
TEXTONLY,"Trace on Highlight",3,56,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Yes",43,56,10,5,L|Arial|10|B|,Yy,SPECIAL>SECONDCLICK|TR1,
TEXTONLY,"Trace Loops",3,62,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Loops",43,62,10,5,L|Arial|10|B|,Ll,,SIM_LOOPS
TEXTONLY,"Change to Tree Based",3,68,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Tree",43,68,10,5,L|Arial|10|B|,Tt,,SIM_CAUSE1
TEXTONLY,"Print Graph",3,74,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Graph",18,74,10,5,L|Arial|10|B|,Gg,PRINT>TR1
TEXTONLY,"Print Eqn",30,74,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"OK",43,74,10,5,L|Arial|10|B|,Oo,PRINT>GR1
TEXTONLY,"Data Table",3,80,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Data",43,80,10,5,L|Arial|10|B|,Dd,WORKBENCH>CAUSES TAB
TEXTONLY,"Select a New Variable to Trace",3,86,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Select",43,86,10,5,L|AriaL|10|B|,Ss,,VARIABLES_2
TOOL,"TR1",55,1,44,98,,,WORKBENCH>CAUSES STRIP
TOOL,"GR1",1,8,53,40,,,WORKBENCH>DOCUMENT
BUTTON,"Help",5,93,20,5,||Arial|10|B|,Hh,CUSTOM>HELP3
BUTTON,"Exit to
Simulation",30,93,20,5,||Arial|10|B|,EeXx,SPECIAL>SETWBITEM|PRDPRD,\
CONTROL
SETWB,"",0,0,0,0,,,,SIM_CAUSE2

:SCREEN SIM_USE
TEXTONLY,"USES of -",36,2,0,0,L||16|B|255-0-0|,
WBVAR,"",51,2,0,0,L|Arial|16|B|0-125-125|,
TEXTONLY,"OPTIONS",21,50,0,0,L|Arial|16|B|255-0-0|,
TEXTONLY,"Trace on Highlight",3,56,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Yes",43,56,10,5,L|Arial|10|B|,Yy,SPECIAL>SECONDCLICK|TR1,
TEXTONLY,"Trace Loops",3,62,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Loops",43,62,10,5,L|Arial|10|B|,Ll,,SIM_LOOPS
TEXTONLY,"Change to Tree Based",3,68,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Tree",43,68,10,5,L|Arial|10|B|,Tt,,SIM_CAUSE1
TEXTONLY,"Change to Graph Based",3,74,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"Graph",43,74,10,5,L|Arial|10|B|,Gg,,SIM_CAUSE2

```
TEXTONLY,”Print Tree”,3,80,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Print”,16,80,10,5,L|Arial|10|B|,Pp,PRINT>TR1,
TEXTONLY,”Print Graph”,28,80,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”OK”,43,80,10,5,L|Arial|10|B|,Oo,PRINT>GR1
TEXTONLY,”Select a New Variable to Trace”,3,86,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Select”,43,86,10,5,L|AriaL|10|B|,Ss,,VARIABLES_3
TOOL,”TR1”,2,7,96,42,,,WORKBENCH>USES TREE
TOOL,”GR1”,55,50,43,49,,,WORKBENCH>STRIP GRAPH
BUTTON,”Help”,5,93,20,5,I|Arial|10|B|,Hh,CUSTOM>HELP3
BUTTON,”Exit to
Simulation”,30,93,20,5,I|Arial|10|B|,EeXx,SPECIAL>SETWBITEM|PRDPRD,\
CONTROL
SETWB,””,0,0,0,0,,,,SIM_USE
```

:SCREEN SIM_LOOPS

```
TEXTONLY,”LOOPS CAUSAL TRACING -“,1,2,50,0,L|||B|255-0-0
WBVAR,””,35,2,0,0,L|Arial|12|B|0-125-125|,
TEXTONLY,”OPTIONS”,21,50,0,0,L|Arial|16|B|255-0-0|,
TEXTONLY,”Trace on Highlight”,3,56,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Yes”,43,56,10,5,L|Arial|10|B|,Yy,SPECIAL>SECONDCLICK|TR1,
TEXTONLY,”Change to Tree Based”,3,62,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Tree”,43,62,10,5,L|Arial|10|B|,Tt,,SIM_CAUSE1
TEXTONLY,”Change to Graph Based”,3,68,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Graph”,43,68,10,5,L|Arial|10|B|,Gg,,SIM_CAUSE2
TEXTONLY,”Print Loops”,3,74,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Print”,18,74,10,5,L|Arial|10|B|,Pp,PRINT>TR1,
TEXTONLY,”Print Eqn”,30,74,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”OK”,43,74,10,5,L|Arial|10|B|,Oo,PRINT>GR1
TEXTONLY,”Find Variable Uses”,3,80,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Uses”,43,80,10,5,L|Arial|10|B|,Uu,,SIM_USE
TEXTONLY,”Select a New Variable to Trace”,3,86,0,0,L|Arial|12|B|0-0-125|,
BUTTON,”Select”,43,86,10,5,L|AriaL|10|B|,Ss,,VARIABLES_4
TOOL,”TR1”,55,1,44,98,,,WORKBENCH>LOOPS
TOOL,”GR1”,1,8,53,40,,,WORKBENCH>DOCUMENT
BUTTON,”Help”,5,93,20,5,I|Arial|10|B|,Hh,CUSTOM>HELP3
BUTTON,”Exit to Simulation”,30,93,20,5,I|Arial|10|B|,EeXx,SPECIAL>SETWBITEM|\
PRDPRD,CONTROL
SETWB,””,0,0,0,0,,,,SIM_LOOPS
```

:SCREEN SIM_DIFF

```
TEXTONLY,”Differences Between First Two Loaded Scenarios”\
,0,5,100,0,C|Arial|20|B|255-0-0|,
TOOL,”T1”,5,15,90,70,,,WORKBENCH>RUNS COMPARE
BUTTON,”Exit to Analysis”,20,90,25,0,L,EeXx,,CONTROL,
BUTTON,”Print”,55,90,25,0,L,Pp,PRINT>T1,CONTROL,
```

:SCREEN VARIABLES

```
TEXTONLY,”VARIABLE SELECTION”,30,2,0,0,L||18|B|255-0-0|,
TEXTONLY,”OPTIONS”,42,10,0,0,L|Arial|16|I|0-125-125|,
```

```
TEXTONLY,"Instantaneous Productivity",25,18,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"INSPRD",10,18,12,5,L|Arial|10|B|,Ii,SPECIAL>SETWBITEM|INSPRD,\
SIM_ANALYZE,
TEXTONLY,"Perceived Development Productivity",25,24,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PRDPRD",10,24,12,5,L|Arial|10|B|,Pp,SPECIAL>SETWBITEM|PRDPRD,\
SIM_ANALYZE,
TEXTONLY,"Productivity in 40 Days Period",25,30,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"P®DPER",10,30,12,5,L|Arial|10|B|,Dd,SPECIAL>SETWBITEM|PRDPER,\
SIM_ANALYZE,
TEXTONLY,"Tasks Developed in 40 Days Period",25,36,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PR(T)KDV",10,36,12,5,L|Arial|10|B|,Tt,SPECIAL>SETWBITEM|PRTKDV,\
SIM_ANALYZE,
TEXTONLY,"Person Days Spent in Period",25,42,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PR(M)D",10,42,12,5,L|Arial|10|B|,Mm,SPECIAL>SETWBITEM|PRMD,\
SIM_ANALYZE,
TEXTONLY,"Fraction of WF Experienced",25,48,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"FRWFEX",10,48,12,5,L|Arial|10|B|,Ff,SPECIAL>SETWBITEM|FRWFEX,\
SIM_ANALYZE,
TEXTONLY,"Actual Fraction of Man-Days on Project",25,54,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"AFMDPJ",10,54,12,5,L|Arial|10|B|,Aa,SPECIAL>SETWBITEM|AFMDPJ,\
SIM_ANALYZE,
TEXTONLY,"Communications Overhead",25,60,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"COMMOH",10,60,12,5,L|Arial|10|B|,Cc,SPECIAL>SETWBITEM|COMMOH,\
SIM_ANALYZE,
TEXTONLY,"SW Development Productivity",25,66,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"SDVPRD",10,66,12,5,L|Arial|10|B|,Ss,SPECIAL>SETWBITEM|SDVPRD,\
SIM_ANALYZE,
TEXTONLY,"Daily Manpower for Training",25,72,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"DMPTR(N)",10,72,12,5,L|Arial|10|B|,Nn,SPECIAL>SETWBITEM|DMPTRN,\
SIM_ANALYZE,
TEXTONLY,"Cummulative Rework Man-Days",25,78,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"CMR(W)MD",10,78,12,5,L|Arial|10|B|,Ww,SPECIAL>SETWBITEM|CMRWMD,\
SIM_ANALYZE,
TEXTONLY,"Period's Defect Density",25,84,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PR(D)FDS",10,84,12,5,L|Arial|10|B|,Dd,SPECIAL>SETWBITEM|PRDFDS,\
SIM_ANALYZE,
TEXTONLY,"Error Generation Rate",25,90,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"ERR(G)RT",10,90,12,5,L|Arial|10|B|,Ll,SPECIAL>SETWBITEM|ERRGRT,\
SIM_ANALYZE,
BUTTON,"CANCE(L)",70,75,20,8,L|Arial|10|B|,Ll,,SIM_ANALYZE,
BUTTON,"Exit to Simulation",70,85,20,8,L|Arial|10|B|,EeXx,,CONTROL
```

:SCREEN VARIABLES_1

```
TEXTONLY,"VARIABLE SELECTION",30,2,0,0,L||18|B|255-0-0|,
TEXTONLY,"OPTIONS",42,10,0,0,L|Arial|16|I|0-125-125|,
TEXTONLY,"Instantaneous Productivity",25,18,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"INSPRD",10,18,12,5,L|Arial|10|B|,Ii,SPECIAL>SETWBITEM|INSPRD,\
SIM_CAUSE1,
TEXTONLY,"Perceived Development Productivity",25,24,0,0,L|Arial|12|B|0-0-125|,
```

```
BUTTON,"PRDPRD",10,24,12,5,L|Arial|10|B|,Pp,SPECIAL>SETWBITEM|PRDPRD,\
SIM_CAUSE1,
TEXTONLY,"Productivity in 40 Days Period",25,30,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"P®DPER",10,30,12,5,L|Arial|10|B|,Dd,SPECIAL>SETWBITEM|PRDPER,\
SIM_CAUSE1,
TEXTONLY,"Tasks Developed in 40 Days Period",25,36,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PR(T)KDV",10,36,12,5,L|Arial|10|B|,Tt,SPECIAL>SETWBITEM|PRTKDV,\
SIM_CAUSE1,
TEXTONLY,"Person Days Spent in Period",25,42,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PR(M)D",10,42,12,5,L|Arial|10|B|,Mm,SPECIAL>SETWBITEM|PRMD,\
SIM_CAUSE1,
TEXTONLY,"Fraction of WF Experienced",25,48,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"FRWFEX",10,48,12,5,L|Arial|10|B|,Ff,SPECIAL>SETWBITEM|FRWFEX,\
SIM_CAUSE1,
TEXTONLY,"Actual Fraction of Man-Days on Project",25,54,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"AFMDPJ",10,54,12,5,L|Arial|10|B|,Aa,SPECIAL>SETWBITEM|AFMDPJ,\
SIM_CAUSE1,
TEXTONLY,"Communications Overhead",25,60,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"COMMOH",10,60,12,5,L|Arial|10|B|,Cc,SPECIAL>SETWBITEM|COMMOH,\
SIM_CAUSE1,
TEXTONLY,"SW Development Productivity",25,66,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"SDVPRD",10,66,12,5,L|Arial|10|B|,Ss,SPECIAL>SETWBITEM|SDVPRD,\
SIM_CAUSE1,
TEXTONLY,"Daily Manpower for Training",25,72,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"DMPTR(N)",10,72,12,5,L|Arial|10|B|,Nn,SPECIAL>SETWBITEM|DMPTRN,\
SIM_CAUSE1,
TEXTONLY,"Cummulative Rework Man-Days",25,78,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"CMR(W)MD",10,78,12,5,L|Arial|10|B|,Ww,SPECIAL>SETWBITEM|CMRWMD,\
SIM_CAUSE1,
TEXTONLY,"Period's Defect Density",25,84,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PR(D)FDS",10,84,12,5,L|Arial|10|B|,Dd,SPECIAL>SETWBITEM|PRDFDS,\
SIM_CAUSE1,
TEXTONLY,"Error Generation Rate",25,90,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"ERR(G)RT",10,90,12,5,L|Arial|10|B|,Ll,SPECIAL>SETWBITEM|ERRGRT,\
SIM_CAUSE1,
BUTTON,"CANCE(L)",70,75,20,8,L|Arial|10|B|,Ll,,SIM_CAUSE1,
BUTTON,"Exit to Simulation",70,85,20,8,L|Arial|10|B|,EeXx,,CONTROL
```

:SCREEN VARIABLES_2

```
TEXTONLY,"VARIABLE SELECTION",30,2,0,0,L||18|B|255-0-0|,
TEXTONLY,"OPTIONS",42,10,0,0,L|Arial|16|I|0-125-125|,
TEXTONLY,"Instantaneous Productivity",25,18,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"INSPRD",10,18,12,5,L|Arial|10|B|,Ii,SPECIAL>SETWBITEM|INSPRD,\
SIM_CAUSE2,
TEXTONLY,"Perceived Development Productivity",25,24,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PRDPRD",10,24,12,5,L|Arial|10|B|,Pp,SPECIAL>SETWBITEM|PRDPRD,\
SIM_CAUSE2,
TEXTONLY,"Productivity in 40 Days Period",25,30,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"P®DPER",10,30,12,5,L|Arial|10|B|,Dd,SPECIAL>SETWBITEM|PRDPER,\
```

```
SIM_CAUSE2,
TEXTONLY,"Tasks Developed in 40 Days Period",25,36,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PR(T)KDV",10,36,12,5,L|Arial|10|B|,Tt,SPECIAL>SETWBITEM|PRTKDV,\
SIM_CAUSE2,
TEXTONLY,"Person Days Spent in Period",25,42,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PR(M)D",10,42,12,5,L|Arial|10|B|,Mm,SPECIAL>SETWBITEM|PRMD,\
SIM_CAUSE2,
TEXTONLY,"Fraction of WF Experienced",25,48,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"FRWFEX",10,48,12,5,L|Arial|10|B|,Ff,SPECIAL>SETWBITEM|FRWFEX,\
SIM_CAUSE2,
TEXTONLY,"Actual Fraction of Man-Days on Project",25,54,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"AFMDPJ",10,54,12,5,L|Arial|10|B|,Aa,SPECIAL>SETWBITEM|AFMDPJ,\
SIM_CAUSE2,
TEXTONLY,"Communications Overhead",25,60,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"COMMOH",10,60,12,5,L|Arial|10|B|,Cc,SPECIAL>SETWBITEM|COMMOH,\
SIM_CAUSE2,
TEXTONLY,"SW Development Productivity",25,66,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"SDVPRD",10,66,12,5,L|Arial|10|B|,Ss,SPECIAL>SETWBITEM|SDVPRD,\
SIM_CAUSE2,
TEXTONLY,"Daily Manpower for Training",25,72,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"DMPTR(N)",10,72,12,5,L|Arial|10|B|,Nn,SPECIAL>SETWBITEM|DMPTRN,\
SIM_CAUSE2,
TEXTONLY,"Cummulative Rework Man-Days",25,78,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"CMR(W)MD",10,78,12,5,L|Arial|10|B|,Ww,SPECIAL>SETWBITEM|CMRWMD,\
SIM_CAUSE2,
TEXTONLY,"Period's Defect Density",25,84,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PR(D)FDS",10,84,12,5,L|Arial|10|B|,Dd,SPECIAL>SETWBITEM|PRDFDS,\
SIM_CAUSE2,
TEXTONLY,"Error Generation Rate",25,90,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"ERR(G)RT",10,90,12,5,L|Arial|10|B|,Ll,SPECIAL>SETWBITEM|ERRGRT,\
SIM_CAUSE2,
BUTTON,"CANCE(L)",70,75,20,8,L|Arial|10|B|,Ll,,SIM_CAUSE2,
BUTTON,"Exit to Simulation",70,85,20,8,L|Arial|10|B|,EeXx,,CONTROL
```

:SCREEN VARIABLES_3

```
TEXTONLY,"VARIABLE SELECTION",30,2,0,0,L||18|B|255-0-0|,
TEXTONLY,"OPTIONS",42,10,0,0,L|Arial|16|I|0-125-125|,
TEXTONLY,"Instantaneous Productivity",25,18,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"INSPRD",10,18,12,5,L|Arial|10|B|,Ii,SPECIAL>SETWBITEM|INSPRD,\
SIM_USE,
TEXTONLY,"Perceived Development Productivity",25,24,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PRDPRD",10,24,12,5,L|Arial|10|B|,Pp,SPECIAL>SETWBITEM|PRDPRD,\
SIM_USE,
TEXTONLY,"Productivity in 40 Days Period",25,30,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"P®DPER",10,30,12,5,L|Arial|10|B|,Dd,SPECIAL>SETWBITEM|PRDPER,\
SIM_USE,
TEXTONLY,"Tasks Developed in 40 Days Period",25,36,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PR(T)KDV",10,36,12,5,L|Arial|10|B|,Tt,SPECIAL>SETWBITEM|PRTKDV,\
SIM_USE,
```

```
TEXTONLY,"Person Days Spent in Period",25,42,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PR(M)D",10,42,12,5,L|Arial|10|B|,Mm,SPECIAL>SETWBITEM|PRMD,\
SIM_USE,
TEXTONLY,"Fraction of WF Experienced",25,48,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"FRWFEX",10,48,12,5,L|Arial|10|B|,Ff,SPECIAL>SETWBITEM|FRWFEX,\
SIM_USE,
TEXTONLY,"Actual Fraction of Man-Days on Project",25,54,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"AFMDPJ",10,54,12,5,L|Arial|10|B|,Aa,SPECIAL>SETWBITEM|AFMDPJ,\
SIM_USE,
TEXTONLY,"Communications Overhead",25,60,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"COMMOH",10,60,12,5,L|Arial|10|B|,Cc,SPECIAL>SETWBITEM|COMMOH,\
SIM_USE,
TEXTONLY,"SW Development Productivity",25,66,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"SDVPRD",10,66,12,5,L|Arial|10|B|,Ss,SPECIAL>SETWBITEM|SDVPRD,\
SIM_USE,
TEXTONLY,"Daily Manpower for Training",25,72,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"DMPTR(N)",10,72,12,5,L|Arial|10|B|,Nn,SPECIAL>SETWBITEM|DMPTRN,\
SIM_USE,
TEXTONLY,"Cummulative Rework Man-Days",25,78,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"CMR(W)MD",10,78,12,5,L|Arial|10|B|,Ww,SPECIAL>SETWBITEM|CMRWMD,\
SIM_USE,
TEXTONLY,"Period's Defect Density",25,84,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PR(D)FDS",10,84,12,5,L|Arial|10|B|,Dd,SPECIAL>SETWBITEM|PRDFDS,\
SIM_USE,
TEXTONLY,"Error Generation Rate",25,90,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"ERR(G)RT",10,90,12,5,L|Arial|10|B|,Ll,SPECIAL>SETWBITEM|ERRGRT,\
SIM_USE,
BUTTON,"CANCE(L)",70,75,20,8,L|Arial|10|B|,Ll,,SIM_USE,
BUTTON,"Exit to Simulation",70,85,20,8,L|Arial|10|B|,EeXx,,CONTROL
```

:SCREEN VARIABLES_4

```
TEXTONLY,"VARIABLE SELECTION",30,2,0,0,L||18|B|255-0-0|,
TEXTONLY,"OPTIONS",42,10,0,0,L|Arial|16|I|0-125-125|,
TEXTONLY,"Instantaneous Productivity",25,18,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"INSPRD",10,18,12,5,L|Arial|10|B|,Ii,SPECIAL>SETWBITEM|INSPRD,\
SIM_LOOPS,
TEXTONLY,"Perceived Development Productivity",25,24,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PRDPRD",10,24,12,5,L|Arial|10|B|,Pp,SPECIAL>SETWBITEM|PRDPRD,\
SIM_LOOPS,
TEXTONLY,"Productivity in 40 Days Period",25,30,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"P®DPER",10,30,12,5,L|Arial|10|B|,Dd,SPECIAL>SETWBITEM|PRDPER,\
SIM_LOOPS,
TEXTONLY,"Tasks Developed in 40 Days Period",25,36,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PR(T)KDV",10,36,12,5,L|Arial|10|B|,Tt,SPECIAL>SETWBITEM|PRTKDV,\
SIM_LOOPS,
TEXTONLY,"Person Days Spent in Period",25,42,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PR(M)D",10,42,12,5,L|Arial|10|B|,Mm,SPECIAL>SETWBITEM|PRMD,\
SIM_LOOPS,
TEXTONLY,"Fraction of WF Experienced",25,48,0,0,L|Arial|12|B|0-0-125|,
```

```
BUTTON,"FRWFEX",10,48,12,5,L|Arial|10|B|,Ff,SPECIAL>SETWBITEM|FRWFEX,\
SIM_LOOPS,
TEXTONLY,"Actual Fraction of Man-Days on Project",25,54,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"AFMDPJ",10,54,12,5,L|Arial|10|B|,Aa,SPECIAL>SETWBITEM|AFMDPJ,\
SIM_LOOPS,
TEXTONLY,"Communications Overhead",25,60,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"COMMOH",10,60,12,5,L|Arial|10|B|,Cc,SPECIAL>SETWBITEM|COMMOH,\
SIM_LOOPS,
TEXTONLY,"SW Development Productivity",25,66,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"SDVPRD",10,66,12,5,L|Arial|10|B|,Ss,SPECIAL>SETWBITEM|SDVPRD,\
SIM_LOOPS,
TEXTONLY,"Daily Manpower for Training",25,72,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"DMPTR(N)",10,72,12,5,L|Arial|10|B|,Nn,SPECIAL>SETWBITEM|DMPTRN,\
SIM_LOOPS,
TEXTONLY,"Cummulative Rework Man-Days",25,78,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"CMR(W)MD",10,78,12,5,L|Arial|10|B|,Ww,SPECIAL>SETWBITEM|CMRWMD,\
SIM_LOOPS,
TEXTONLY,"Period's Defect Density",25,84,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"PR(D)FDS",10,84,12,5,L|Arial|10|B|,Dd,SPECIAL>SETWBITEM|PRDFDS,\
SIM_LOOPS,
TEXTONLY,"Error Generation Rate",25,90,0,0,L|Arial|12|B|0-0-125|,
BUTTON,"ERR(G)RT",10,90,12,5,L|Arial|10|B|,Ll,SPECIAL>SETWBITEM|ERRGRT,\
SIM_LOOPS,
BUTTON,"CANCE(L)",70,75,20,8,L|Arial|10|B|,Ll,,SIM_LOOPS,
```

APPENDIX D.

SMFS VENSIM MODEL EQUATIONS

This appendix provides an enumerated and alphabetized listing of the equations that comprise the SMFS model as converted from Dynamo into Vensim, and as modified to allow user interaction. The equation listed follows the Vensim equation structure to facilitate their understanding. Appendix A provides an explanation of the structure and syntax of Vensim equations. The following list of variables is currently not in use during simulations (as reported by Vensim during model compilation) using the current version of the interface.

1. AFMPQA
2. ALLERR
3. ALLRWK
4. CMDSI KDSI
5. CMDVMD
6. CMERD KDSI
7. CMERES
8. CMRWMD
9. CMTRMD
10. CRDVWF
11. CRQAWF
12. CRRWWF
13. CUMMD TD
14. DEVMD
15. FNCOST
16. FNERES
17. FNERR
18. FNPRDT
19. FNQAMD
20. FNRWMD
21. FNTIME
22. FNTRMD
23. FRMPQ1
24. FRWFEX PCT
25. INDCDT
26. INSPRD
27. INUDST
28. IPRJSZ
29. IRDVDT
30. PJBSZT KDSI
31. PRCMPL
32. PRCTDT
33. PRDFDS
34. PRDPER
35. PRQAMD PERIOD
36. PTKTST
37. PTRPTC
38. RPPROD
39. SCHADT
40. TEAMSZ
41. TM
42. TMSTOP
43. WFNEED
44. WFS2

****

Causal Variable Listing

***~

VERSION 1
October 1995

1. ACTSPD=CUMTKT/(CMTSMD+0.001)
~ TASKS/MAN-DAY
~ ACTUAL TESTING PRODUCTIVITY
|

2. ADJQA=TADJQA(SCHPR)
~ PERCENT
~ PERCENT ADJUSTMENT IN PFMPQA
|

3. ADMPPS=1
~ DAY/DAY
~ AVERAGE DAILY MANPOWER PER STAFF
|

4. AEGRT=(ERRSRT+BDFXGR)*FRAERR
~ ERRORS/DAY
~ ACIVE ERRORS GENERATION RATE
|

5. AERGRT=SDVRT*SMOOTH(AERRDS,TSAEDS)*MAERED
~ ERRORS/DAY
~ ACTIVE ERRORS REGENERATION RATE
|

6. AERRDS=UDAVER/(CUMTQA+0.1)
~ ERRORS/TASK
~ ACTIVE ERROR DENSITY
|

7. AERRFR=TERMFR(PJBAWK)
~ 1/DAYS
~ ACTIVE ERRORS RETIRING FRACTION
|

8. AERRRT=UDAVER*AERRFR
~ ERRORS/DAY
~ ACTIVE ERRORS RETIRING RATE
|

9. AFMDPJ=INTEG(WRADJR,NFMDPJ)
~ DIMENSIONLESS
~ ACTUAL FRACTION OF A MAN-DAY ON PROJECT
|

10. AFMPQA=ACTIVE INITIAL(PFMPQA*(1+ADJQA),PFMPQA)
~ DIMENSIONLESS
~ ACTUAL FRACTION OF MANPOWER FOR QA
|

11. ALESER=UDAVER+UDPVER+CMRWET
~ ERRORS
~ ALL ERRORS THAT ESCAPED AND WERE GENERATED
|

12. ALLERR=PTDTER+DTCERR+CMRWED+UDAVER+UDPVER+CMRWET
~ ERRORS
~ ALL ERRORS
|

13. ALLRWK=CMRWED+CMRWET
~ ERRORS
~ ALL ERRORS REWORKED ... IN DEVELOPMENT AND TESTING
|

14. ANERPT=MAX(PTDTER/(TSKWK+0.0001),0)
~ ERRORS/TASK
~ AVERAGE # OF ERRORS PER TASK
|

15. ANPPRD=FRWFEX*NPWPEX+(1-FRWFEX)*NPWPNE
~ TASKS/MAN-DAY
~ AVERAGE NOMINAL POTENTIAL PRODUCTIVITY
|

16. AQADLY=10
~ DAYS
~ AVERAGE DELAY FOR QA
|

17. ARTJBM=(MDRPTN+CUMMD-JBSZMD)/DAJBMD
~ MAN-DAYS/DAY
~ RATE OF ADJUSTING THE JOB SIZE IN MAN-DAYS
|

18. ASIMDY=80
~ DAYS
~ AVERAGE ASSIMILATION DELAY
|

19. ASIMRT=WFNEW/ASIMDY
~ PEOPLE/DAY
~ ASSIMILATION RATE OF NEW EMPLOYEES
|

20. ASSPRD=PJDPRD*WTPJDP+PRDPRD*(1-WTPJDP)
~ TASKS/MAN-DAY
~ ASSUMED PRODUCTIVITY
|

21. AVEMPT=673
~ DAYS
~ AVERAGE EMPLOYMENT TIME
|

22. BDFXGR=RWRATE*PBADFX
~ ERRORS/DAY
~ BAD FIXES GENERATE RATE
|

23. BRKDTM=INTEG((TIME STEP*(1/TIME STEP)*(MAX(BRKDTM,IF THEN ELSE (OVWDTH = 0,(Time+TIME STEP),0))-BRKDTM))/TIME STEP,-1)
~
~ TIME OF LAST EXHAUSTION BREAKDOWN
|

24. CELNWH=FTEXWF*MNHPXS
~ MEN
~ CEILING ON NEW HIREES
|

25. CELTWF=CELNWH+WFEXP
~ PEOPLE
~ CEILING ON TOTAL WORKFORCE
|

26. CMDSI=CMTKDV*DSIPTK
~ TASKS
~ CUMULATIVE TASKS DEVELOPED
|

27. CMDSI KDSI=CMDSI/1000
~ TASKS
~ TOTAL KDSI COMPLETED
|

28. CMDVMD=INTEG((TIME STEP*DMPDVT*(1-FREFTS))/TIME STEP,0)
~ MAN DAYS
~ CUMULATVE DEVELOPMENT MAN-DAYS |

29. CMERD=INTEG(ERRDRT,0)
~ ERRORS
~ CUMULATIVE ERRORS DETECTED
|

30. CMERD KDSI=CMERD*(1000/(CMDSI+0.01))
~ DEFECTS/KDSI
~ DEFECT DENSITY PER KDSI
|

31. CMERES=INTEG(ERRSRT,0)
~ ERRORS
~ CUMULATIVE ERRORS THAT ESCAPED
|

32. CMQAMD=INTEG(DMPQA,0)
~ MAN-DAYS
~ CUMULATIVE QA MAN-DAYS
|

33. CMRWED=INTEG(RWRATE,0)
~ ERRORS
~ CUMULATIVE REWORKED ERRORS DURING DEVELOPMENT
|

34. CMRWET=INTEG((DCRTPE+DCRTAE),0)
~ ERRORS
~ CUMULATIVE ERRORS REWORKED IN TESTING PHASE
|

35. CMRWMD=INTEG(DMPRW,0)
~ MAN DAYS
~ CUMULATIVE REWORK MAN-DAYS
|

36. CMTKDV=INTEG(SDVRT,0)
~ TASKS
~ CUMULATIVE TASKS DEVELOPED
|

37. CMTRMD=INTEG(DMPTRN,0)
~
~ CUMULATIVE TRAINING MAN-DAYS
|

38. CMTSMD=INTEG(DMPTST,0)
~ MAN DAYS
~ CUMULATIVE TESTING MAN-DAYS
|

39. COMMOH=TCOMOH(TOTWF)
~ DIMENSIONLESS
~ COMMUNICATION OVERHEAD
|

40. CRDVWF=TOTDMP-DMPQA
~ PERSONS
~ CURRENT DEVELOPMENT WORK FORCE
|

41. CRQAWF=(INTEGER(100*DMPQA))/100
~ PERSONS
~ CURRENT QA WORK FORCE
|

42. CRRWWF=DMPRW
~ PEOPLE
~ CURRENT REWORK WORK FORCE
|

43. CTRLSW=1
~ Zero or One
~ CONTROL SWITCH ... ALLOWS US TO TEST POLICY OF NO OVERWORK
|

44. CUMERG=INTEG(ERRGRT,0)
~ ERRORS
~ CUMULATIVE ERRORS GENERATED DIRECTLY DURING WORKING
|

45. CUMMD=INTEG(TOTDMP,0.0001)
~ MAN DAYS
~ CUMULATIVE MAN-DAYS EXPENDED
|

46. CUMMD TD=CUMMD-CMQAMD
~ PERSON DAYS
~ PROGRAMMING PERSON DAYS EXPENDED TO DATE
|

47. CUMTKT=INTEG(TSRATE,0)
~ TASKS
~ CUMULATIVE TASKS TESTED
|

48. CUMTQA=INTEG((QART-TSRATE),0)
~ TASKS
~ CUMULATIVE TASKS QA'ED
|

49. DAJBMD=TDAJMD(TIMERM)
~ DAYS
~ DELAY IN ADJUSTING JOB'S SIZE IN MAN DAYS
|

50. DCRTAE=MIN(TSRATE*AERRDS,UDAVER/TIME STEP)
~ ERRORS/DAY
~ DETECTION/CORRECTION RATE OF ACTIVE ERRORS
|

51. DCRTPE=MIN(TSRATE*PERRDS,UDPVER/TIME STEP)
~ ERRORS/DAY
~ DETECT/CORRECT RATE OF PASSIVE ERRORS
|

52. DESECR=ACTIVE INITIAL(DTCERR/DESRWD,0)
~ ERRORS/DAY
~ DESIRED ERROR CORRECTION RATE
|

53. DESRWD=15
~ DAYS
~ DESIRED REWORK DELAY
|

54. DEVMD=INITIAL(DEVPRT*TOTMD)
~
~ DEVELOPMENT MAN DAYS
|

55. DEVPRT=0.8
~
~ PERCENT OF EFFORT ASSUMED NEEDED FOR DEVELOPMENT
|

56. DLINCT=10
~ DAYS
~ AVERAGE DELAY IN INCORPORATING DISCOVERED TASKS
|

57. DMPATR=TOTDMP-DMPTRN
~ MAN-DAYS/DAY
~ DAILY MANPOWER AVAILABLE AFTER TRAINING
|

58. DMPDVT=DMPSWP-DMPRW
~ MAN-DAYS/DAYS
~ DAILY MANPOWER FOR DEVELOPMENT/ TESTING
|

59. DMPQA=MIN(((FRMPQA/100)*TOTDMP),0.9*DMPATR)
~ MAN-DAYS/DAY
~ DAILY MANPOWER ALLOCATED FOR QA
|

60. DMPRW=ACTIVE INITIAL(MIN((DESECR*PRWMPE),DMPSWP),0)
~ MAN-DAYS/DAY
~ DAILY MANPOWER ALLOCATED FOR REWORK
|

61. DMPSDV=DMPDVT*(1-FREFTS)
~ MAN-DAYS/DAY
~ DAILY MANPOWER FOR SOFTWARE DEVELOPMENT
|

62. DMPSWP=DMPATR-DMPQA
~ MAN-DAYS/DAY
~ DAILY MANPOWER FOR SOFTWARE PRODUCTION
|

63. DMPTRN=WFNEW*TRPNHR
~ MAN DAYS/DAY
~ DAILY MANPOWER FOR TRAINING
|

64. DMPTST=DMPDVT*FREFTS
~ MAN DAYS/DAY
~ DAILY MANPOWER FOR TESTING
|

65. DSIPTK=60
~
~ DSI PER TASK
|

66. DTCERR=INTEG((ERRDRT-RWRATE),0)
~ ERRORS
~ DETECTED ERRORS |

67. ERRDRT=MIN(PERDRT,PTDTER/TIME STEP)
~ ERRORS/DAY
~ ERROR DETECTION RATE
|

68. ERRDSY=ANERPT*1000/DSIPTK
~ ERRORS/KDSI
~ ERROR DENSITY
|

69. ERRGRT=SDVRT*ERRPTK
~ ERRORS/DAY
~ ERROR GENERATION RATE
|

70. ERRPTK=NERPTK*MERGSP*MERGWM
~ ERRORS/TASK
~ ERRORS PER TASK
|

71. ERRSRT=QART*ANERPT
~ ERRORS/DAY
~ ERROR ESCAPE RATE
|

72. EWKRTS=IF THEN ELSE(WKRTS >= AFMDPJ,1,0.75)
~ DIMENSIONLESS
~ EFFECT OF WORK RATE SOUGHT
|

73. EXHDDY=20
~ DAYS
~ EXHAUSTION DEPLETION DELAY TIME
|

74. EXHLEV=INTEG((RIEXHL-RDEXHL),0)
~ EXHAUST UNITS
~ EXHAUSTION LEVEL
|

75. EXPTRR=MIN(WFEXP/TIME STEP,TRNFRT-NEWTRR)
~ PEOPLE/DAY
~ EXPERIENCED EMPLOYEES TRANSFER RATE
|

76. EXSABS=MAX(0,(TEXABS(TMDPSN/MDRM)*MDRM-TMDPSN))
~ MAN-DAYS
~ MAN-DAY EXCESSES THAT WILL BE ABSOBED
|

77. FADHWO=TFAHWO(RSZDCT/(MSZTWO+0.001))
~
~ FRACTION OF ADDITIONAL TASKS ADDING TO MAN-DAYS |

78. FINAL TIME=IF THEN ELSE(PJBAWK >= 0.995,Time,MAXLEN)
~ ~ |

79. FNCOST=INTEG((TIME STEP*TOTDMP*IF THEN ELSE(PJBAWK >= 0.995,0,1))/
TIME STEP,0)
~ MAN-DAYS
~ FINAL COST IN MAN-DAYS
|

80. FNERD=INTEG((TIME STEP*ERRDRT*IF THEN ELSE(PJBAWK >= 0.995,0,1))/
TIME STEP,0)
~ ERRORS
~ CUMULATIVE ERRORS DETECTED
|

81. FNERES=FNERG-FNERD
~ ERRORS
~ ERRORS THAT ESCAPED QA
|

82. FNERG=INTEG((TIME STEP*ERRGRT*IF THEN ELSE(PJBAWK >= 0.995,0,1))/
TIME STEP,0)
~ ERRORS
~ CUMULATIVE ERRORS GENERATED
|

83. FNERR=INTEG(((IF THEN ELSE(PJBAWK >= 0.995,FNERR,ALESER)/
TIME STEP)-FNERR/TIME STEP),0)
~ ~ |

84. FNPRDT=100*FNERD/MAX(1,FNERG)
~ Percent
~ PERCENT DETECTED
|

85. FNQAMD=INTEG((TIME STEP*DMPQA*IF THEN ELSE(PJBAWK >= 0.995,0,1))/
TIME STEP,0)
~ MAN-DAYS
~ CUMULATIVE QA MAN-DAYS
|

86. FNRWMD=INTEG((TIME STEP*DMPRW*IF THEN ELSE(PJBAWK >= 0.995,0,1))/
TIME STEP,0)
~ MAN-DAYS
~ CUMULATIVE REWORK MAN-DAYS
|

87. FNTIME=INTEG(IF THEN ELSE(PJBAWK >= 0.995,0,1),0)
~ ~ |

88. FNTRMD=INTEG((TIME STEP*DMPTRN*IF THEN ELSE(PJBAWK >= 0.995,0,1))/
TIME STEP,0)
~
~ CUMULATIVE TRAINING MAN-DAYS
|

89. FRAERR=TFRAER(PJBAWK)
~ DIMENSIONLESS
~ FRACTION OF ESCAPING ERRORS THAT WILL BE ACTIVE
|

90. FREFTS=TFEFTS(TSKPRM/PJBSZ)
~ DIMENSIONLESS
~ FRACTION OF EFFORT FOR SYSTEM TESTING
|

91. FRMPQ1=FRMPQA
~ PERSONS
~ FRACTION OF MANPOWER FOR Q1
|

92. FRMPQA=GAME(10)
~ PERSONS
~ FRACTION OF MANPOWER ALLOCATED FOR QA
|

93. FRWFEX=(INTEGER((WFEXP/TOTWF)*10000))/10000
~ DIMENSIOLESS
~ FRACTION OF WF THAT IS EXPERIENCED
|

94. FRWFEX PCT=FRWFEX*100
~ DIMENSIOLESS
~ FRACTION OF WF THAT IS EXPERIENCED
|

95. FTEQWF=TOTWF*ADMPPS
~ PERSONS
~ FULL TIME EQUIVALENT WF
|

96. FTEXWF=WFEXP*ADMPPS
~ MEN
~ FULL-TIME-EQUIVALENT EXPERIENCED WF
|

97. HIREDY=40
~ DAYS
~ HIRING DELAY
|

98. HIRERT=MAX(0,WFGAP/HIREDY)
~ PEOPLE/DAY
~ HIRING RATE
|

99. INDCDT=Time+TIMEPR
~
~ INDICATED COMPLETION DATE
|

100. INITIAL TIME=0
~
~ ASSUMED WITH FINAL_TIME = LENGTH
|

101. INSPRD=(SDVRT*TIME STEP)/TOTDMP
~
~ INSTANTANEOUS PRODUCTIVITY
|

102. INUDST=0.5
~ DIMENSIONLESS
~ INITIAL UNDERSTAFFING FACTOR
|

103. IPRJSZ=INITIAL((RJBDSI)*(1-UNDEST))
~ DSI
~ INITIAL PROJECT SIZE IN DSI
|

104. IRDVDT=(RTINCT/ASSPRD)*(FADHWO)
~
~ RATE OF INCREASE IN DEVELOPMENT MAN- DAYS DUE TO DISCOVERED TASKS
|

105. IRTSDT=(RTINCT/PRTPRD)*(FADHWO)
~ MD/D
~ RATE OF INCREASE IN TESTING MAN DAYS DUE TO DISCOVERED TASKS
|

106. JBSZMD=TOTMD1
~ MAN DAYS
~ TOTAL JOB SIZE IN MAN DAYA |

107. MAERED=TMERED(SMOOTH(AERRDS*1000/DSIPTK,TSAEDS))
~
~ MULTIPLIER TO ACTIVE ERROR REGENERATION DUE TO ERROR DENSITY (DIMEN
|

108. MAXLEN=1000
~ ~ |

109. MAXMHR=INITIAL(1)
~ DIMENSIONLESS
~ MAXIMUM BOOST IN MAN-HOURS
|

110. MAXSHR=(OVWDTH*FTEQWF*MAXMHR)*WTOVWK
~ MAN-DAYS
~ MAXIMUM SHORTAGE IN MAN-DAYS THAT CAN BE HANDLED
|

111. MDEFED=TMDFED(ERRDSY)
~ DIMENSIONLESS
~ MULTIPLIER TO DETECTION EFFORT DUE TO ERROR DENSITY
|

112. MDHDL=IF THEN ELSE(PMDSHR >= 0,MIN(MAXSHR,PMDSHR),-EXSABS)* CTRLSW
~ MAN-DAYS
~ MAN-DAYS THAT WILL BE HANDLED OR ABSORBED
|

113. MDPNNT=TSKPRM/ASSPRD
~ MAN-DAYS
~ MAN DAYS PERCEIVED STILL NEEDED FOR NEW TASKS
|

114. MDPNRW=DTCERR*PRWMPE
~
~ MAN DAYS PERCEIVED NEEDED FOR REWORKING ALREADY DETECTED ERRORS (MD
|

115. MDPNTS=TSTPRM/PRTPRD
~ MAN-DAYS
~ MAN DAYS PERCEIVED STILL NEEDED FOR TESTING
|

116. MDPRNT=MAX(0,MDRM-MDPNRW-MDPNTS)
~ MAN-DAYS
~ MAN DAYS PERCEIVED REMAINING FOR NEW TASKS |

117. MDRM=MAX(0.0001,JBSZMD-CUMMD)
~ ~ |

118. MDRPTN=MDRM+SHRRPT
~ MAN DAYS
~ MAN DAYS REPORTED STILL NEEDED
|

119. MDSWCH=0
~
~ SWITCH 0 OR 1
|

120. MERGSP=TMEGSP(SCHPR)
~
~ MULTIPLIER TO ERROR GENERATION DUE TO SCHEDULE PRESSURE (DIMENSIONLESS)
|

121. MERGWM=TMEGWM(FRWFEX)
~ DIMENSIONLESS
~ MULTIPLIER TO ERROR GENERATION DUE TO WORKFORCE MIX
|

122. MNHPXS=3
~ MEN/MEN
~ MOST NEW HIREES PER EXPERIENCED STAFF
|

123. MODTEX=TMODEX(EXHLEV/MXEXHT)
~ DIMENSIONLESS
~ EFFECT OF EXHAUSTION ON OVERWORK DURATION THRESHOLD
|

124. MPDMCL=AFMDPJ*(1-COMMOH)
~
~ MULTIPLIER TO PRODUCTIVITY DUE TO MOTIVATION & COMM LOSSES (DIMENSIONLESS)
|

125. MPPTPD=TMPTPD(PJBAWK)
~ DIMENSIONLESS
~ MULTIPLIER TO POTENTIAL PRODUCTIVITY DUE TO LEARNING |

126. MPWDEV=TMPDEV(PJBPWK/100)
~ DIMENSIONLESS
~ MULTIPLIER TO PRODUCTIVITY WEIGHT DUE TO DEVELOMENT
|

127. MPWREX=TMPREX((1-MDPRNT/(JBSZMD-TSSZMD)))
~ DIMENSIONLESS
~ MULTIPLIER TO PRODUCTIVITY WEIGHT DUE TO RESOURCE EXPENDITURE
|

128. MSZTWO=0.01
~
~ MAXIMUM RELATIVE SIZE OF ADDITIONS TOLERATED W/O ADDING TO PROJECT'
|

129. MXEXHT=50
~ EXHAUST UNITS
~ MAXIMUM TOLERABLE EXHAUSTION
|

130. MXSCDX=1e+006
~ DIMENSIONLESS
~ MAX SCHEDULE COMPLETION DATE EXTENSION
|

131. MXTLCD=INITIAL(MXSCDX*TDEV)
~ DAYS
~ MAXIMUM TOLERABLE COMLETION DATE
|

132. NERPK=TNERPK(PJBAWK)
~ ERRORS/KDSI
~ NOMINAL # OF ERRORS COMMITTED PER KDSI
|

133. NERPTK=NERPK*DSIPTK/1000
~ ERRORS/TASK
~ NOMINAL # OF ERRORS COMMITTED PER TASK
|

134. NEWTRR=MIN(TRNFRT,WFNEW/TIME STEP)
~ PEOPLE/DAY
~ NEW EMPLOYEES TRANSFER RATE OUT
|

135. NFMDPJ=0.6
~ DIMENSIONLESS
~ NOMINAL FRACTION OF A MAN-DAY ON PROJECT |

137. NOVWDT=TNOWDT(TIMERM)
~ DAYS
~ NOMINAL OVERWORK DURATION THRESHOLD
|

138. NPWPEX=1
~ TSK/M-D
~ NOMINAL POTENTIAL PRODUCTIVITY OF EXP EMPLOYEE
|

139. NPWPNE=0.5
~ TSK/M-D
~ NOMINAL POTENTIAL PROD OF NEW EMPL.
|

140. NQAMPE=TNQAPE(PJBAWK)
~ MAN-DAYS/ERROR
~ NOMINAL QA MANPOWER NEEDED TO DETECT AVERAGE ERROR
|

141. NRWMPE=TNRWME(PJBAWK)
~ MAN-DAYS/ERROR
~ NOMINAL REWORK MANPOWER NEEDED PER ERROR
|

142. NWRADY=TNWRAD(TIMERM)
~ DAYS
~ NORMAL WORK RATE ADJUSTMENT DELAY
|

143. OVWDTH=NOVWDT*MODTEX
~ DAYS
~ OVERWORK DURATION THRESHOLD
|

144. PBADFX=0.075
~ FRACTION
~ PERCENT BAD FIXES
|

145. PBWKRS=IF THEN ELSE(PMDSHR >= 0,(MDHDL/(FTEQWF*(OVWDTH+0.0001))),(MDHDL/(TMDPSN-MDHDL+0.0001)))
~ PERCENT
~ PERCENT BOOST IN WORK RATE SOUGHT
|

146. PDEVRC=ACTIVE INITIAL(SMOOTH(MAX((100-((MDRPTN-MDPNTS)/(JBSZMD-TSSZMD))*100),PDEVRC),RPTDLY),0)
~
~ PERCENT DEVELOPMENT PERCEIVED COMPLETE %
|

147. PEGRT=(ERRSRT+BDFXGR)*(1-FRAERR)
~ ERRORS/DAY
~ PASSIVE ERRORS GENERATION RATE
|

148. PERDRT=DMPQA/QAMPNE
~ ERRORS/DAY
~ POTENTIAL ERROR DETECTION RATE
|

149. PERRDS=UDPVER/(CUMTQA+0.0001)
~ ERRORS/TASK
~ PASSIVE ERROR DENSITY |

150. PFMPQA=TPFMQA(PJBAWK)*(1+QO/100)
~ DIMENSIONLESS
~ PLANNED FRACTION OF MANPOWER FOR QA
|

151. PJBAWK=CMTKDV/RJBSZ
~ PERCENT
~ PERCENT OF JOB ACTUALLY WORKED
|

152. PJBDSI=INITIAL(RJBDSI*(1-UNDEST))
~
~ PERCEIVED JOB SIZE IN DSI
|

153. PJBPWK=(CMTKDV/PJBSZ)*100
~ PERCENT
~ PERCENT OF JOB PERCEIVED WORKED
|

154. PJBSZ=INTEG(RTINCT,PJBDSI/DSIPTK)
~ TASKS
~ CURRENTLY PERCEIVED JOB SIZE
|

155. PJBSZT=PJBSZ*DSIPTK
~ DSI
~ PERCEIVED JOB SIZE IN LINES OF CODE PERCEIVED JOB SIZE IN DSI
|

156. PJBSZT KDSI=PJBSZT/1000
~ DSI
~ ESTIMATED SYSTEM SIZE (KDSI)
|

157. PJDPRD=TSKPRM/(MDPRNT+0.1)
~ TASKS/MAN-DAY
~ PROJECTED DEVELOPMENT PRODUCTIVITY
|

158. PLTSPD=PJBSZ/TSSZMD
~ TASKS/MAN-DAY
~ PLANNED TESTING PRODUCTIVITY
|

159. PMDSHR=TMDPSN-MDRM
~ MAN DAYS
~ PERCEIVED SHORTAGE IN MAN DAYS
|

160. POTPRD=ANPPRD*MPPTPD
~ TASKS/MAN-DAY
~ POTENTIAL PRODUCTIVTY
|

161. PRCMPL=(CMDSI/PJBSZT)*100
~ PERCENT
~ PERCENT COMPLETE
|

162. PRCTDT=100*CMERD/(CUMERG+0.001)
~ PERCENT
~ PERCENT ERRORS DETECTED
|

163. PRDFDS=PRERD/(MAX(PRTKDV/1000,0.01))
~ DEFECT/KDSI
~ PERIOD'S DEFECT DENSITY
|

164. PRDPER=PRTKDV/PRMD
~ DSI PER PERSON-DAY
~ PRODUCTIVITY IN 40 DAY PERIOD
|

165. PRDPRD=CMTKDV/(CUMMD-CMTSMD)
~ TASKS/MAN-DAY
~ PERCEIVED DEVELOPMENT PRODUCTIVITY
|

167. PRERD=INTEG((ERRDRT-(PRERD/TIME STEP)*M PULSE(Time,
1,TIME STEP,TIME STEP,40)),0)
~ ERRORS
~ DETECTED ERRORS DURING PERIOD |

168. PRMD=INTEG((TOTDMP-(PRMD/TIME STEP)*M PULSE(Time, 1,TIME STEP,TIME STEP,40)),0.1)
~ PERSON-DAY
~ PERSON DAYS SPENT IN PERIOD
|

169. PROJDR=GAME(TDEVINI)
~ DAYS
~ PROJECT DURATION
|

170. PRQAMD=INTEG((DMPQA-(PRQAMD/TIME STEP)*M PULSE(Time, 1,TIME STEP,TIME STEP,40)),0)
~ PERSON-DAYS
~ QA PERSON-DAYS IN PERIOD
|

171. PRQAMD PERIOD=PRQAMD/((PRTKDV+0.01)/1000)
~ PERSON DAYS
~ QA PERSON DAYS PER KDSI DEVELOPED IN PERIOD
|

172. PRTKDV=INTEG((SDVRT*DSIPTK-(PRTKDV/TIME STEP)*M PULSE(Time, 1,TIME STEP,TIME STEP,40)),0.1)
~
~ TASKS DEVELOPED DURING 40 DAY PERIOD
|

173. PRTPRD=SMOOTH((IF THEN ELSE(0 >= CUMTKT,PLTSPD,ACTSPD)),TSTSPD)
~ TASKS/MAN-DAY
~ PERCEIVED TESTING PRODUCTIVITY |
174. PRWMPE=INTEG((RWMPPE-PRWMPE)/TARMPE,0.5)
~ MAN-DAYS/ERROR
~ PERCEIVED REWORK MANPOWER NEEDED PER ERROR
|

175. PSZDCT=TKDSCV/ASSPRD
~ MAN-DAYS
~ PERCEIVED SIZE OF DISCOVERED TASKS IN MAN DAYS
|

176. PTDTER=INTEG((ERRGRT-ERRDRT-ERRSRT),0)
~ ERRORS
~ POTENTIALLY DETECTABLE ERRORS
|

177. PTKTST=CUMTKT/PJBSZ
~ PERCENT
~ PERCENT OF TASKS TESTED |

178. PTRPTC=ACTIVE INITIAL(SMOOTH((100-(MDRPTN/JBSZMD)*100),RPTDLY),0)
~ PERCENT
~ PERCENT OF TASKS REPORTED COMPLETE
|

179. PUTDPD=TPUTDD(PJBPWK)
~ 1/DAY
~ PERCENT OF UNDISCOVERED TASKS DISCOVERED PER DAY
|

180. QAMPNE=NQAMPE*(1/MPDMCL)*MDEFED
~ MAN-DAYS/ERROR
~ QA MANPOWER NEEDED TO DETECT AVERAGE ERROR
|

181. QART=DELAY3(SDVRT,AQADLY)
~ TASKS/DAY
~ FOR QA RATE
|

182. QO=0
~
~ QUALITY OBJECTIVE ... NORMAL QO = 0
|

183. QUITRT=WFEXP/AVEMPT
~ PEOPLE/DAY
~ EXPERIENCED EMPLOYEES QUIT RATE
|

184. RDEXHL=IF THEN ELSE(0 >= RIEXHL,EXHLEV/EXHDDY,0)
~ EXHAUST UNITS/DAY
~ RATE OF DEPLETION IN EXHAUSTION LEVEL
|

185. RIEXHL=TRIXHL((1-AFMDPJ)/(1-NFMDPJ))
~ EXHAUST UNITS/DAY
~ RATE OF INCREASE IN EXHAUSTION LEVEL
|

186. RJBDSI=64000
~
~ REAL JOB SIZE IN DSI
|

187. RJBSZ=INITIAL(RJBDSI/DSIPTK)
~ TASKS
~ REAL JOB SIZE IN TASKS
|

188.RLXTMC=INTEG((IF THEN ELSE(EXHLEV/MXEXHT >= 0.1,1,-RLXTMC/
TIME STEP)-((1/TIME STEP)*RLXTMC*IF THEN ELSE(OVWDTH = 0,1,0))),0)
~
~ VARIABLE THAT CONTROLS TIME TO DE-EXHAUST
|

189. RPPROD=PRDPRD*DSIPTK
~ DSI/MAN-DAY
~ REPORTED PRODUCTIVITY
|

190. RPTDLY=10
~ DAYS
~ REPORTING DELAY
|

191. RSZDCT=PSZDCT/(MDPRNT+0.0001)
~ DIMENSIONLESS
~ RELATIVE SIZE OF DISCOVERED TASKS
|

192. RTDSTK=UNDJTK*PUTDPD/100
~ TASKS/DAY
~ RATE OF DISCOVERING TASKS
|

193. RTINCT=DELAY3(RTDSTK,DLINCT)
~ TASKS/DAY
~ RATE OF INCORPORATING DISCOVERED TASKS INTO PROJECT
|

194. RWMPPE=NRWMPE/MPDMCL
~ MAN-DAYS/ERROR
~ REWORK MANPOWER NEEDED PER ERROR
|

195. RWRATE=DMPRW/RWMPPE
~ ERRORS/DAY
~ REWORK RATE
|

196. SAVEPER=40
~ DAYS
~ CHANGED VALUE TO 40 DAYS VICE 10.
|

197. SCHADT=TSHADT(TIMERM)
~ DAYS
~ SCHEDULE ADJUSTMENT TIME
|

198. SCHCDT=PROJDR
~
~ SCHEDULE COMPLETION DATE
|

199. SCHCOM=1
~ DIMENSIONLESS
~ SCHEDULE COMPRESSION FACTOR
|

200. SCHPR=(TMDPSN-MDRM)/MDRM
~ DIMENSIONLESS
~ SCHEDULE PRESSURE
|

201. SCSWCH=0
~
~ SWITCH 0 OR 1
|

202. SDVPRD=POTPRD*MPDMCL
~ TASKS/MAN-DAY
~ SOFTWARE DEVELOPMENT PRODUCTIVITY
|

203. SDVRT=ACTIVE INITIAL(MIN((DMPSDV*SDVPRD),TSKPRM/TIME STEP),0)
~ TASKS/DAY
~ SOFTWARE DEVELOPMENT RATE
|

204. SHRRPT=PMDSHR-MDHDL
~ MAN-DAYS
~ SHORTAGE REPORTED
|

205. TADJQA(0,0.1,0.2,0.3,0.4,0.5,0,-0.025,-0.15,-0.35,-0.475,-0.5)
~ ~ |

206. TARMPE=10
~ DAYS
~ TIME TO ADJUST PRWMPE
|

207. TCOMOH(0,5,10,15,20,25,30,0,0.015,0.06,0.135,0.24,0.375,0.54)
~ ~ |

208. TDAJMD(0,20,0.5,3)
~ ~ |

209. TDEV=INITIAL(SCSWCH*((19*2.5*EXP(0.38*LN(TOTMD/19)))*SCHCOM)+
(1-SCSWCH)*TDEV1)
~ DAYS
~ TOTAL DEVELOPMENT TIME
|

210. TDEV1=296.79
~ DAYS
~ TIME TO DEVELOP
|

211. TDEVINI=INTEGER(TDEV1)
~ DAYS
~ INITIAL TIME TO DEVELOP
|

212. TEAMSZ=INITIAL((TOTMD/TDEV)/ADMPPS)
~ ~ |

213. TERMFR(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,0,0,0,0,0.01,0.02,0.03,0.04,0.1,0.3,1)
~ ~ |

214. TEXABS(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,0,0.2,0.4,0.55,0.7,0.8,0.9,0.95,1,1,1)
~ ~ |

215. TFAHWO(0,0.2,0.4,0.6,0.8,1,1.2,1.4,1.6,1.8,2,0,0,0,0,0,0,0.7,0.9,0.975,1,1)
~ ~ |

216. TFEFTS(0,0.04,0.08,0.12,0.16,0.2,1,0.5,0.28,0.15,0.05,0)~ ~ |

217. TFRAER(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,1,1,1,1,0.95,0.85,0.5,0.2,0.075,0,0)
~ ~ |

218. TIME STEP=0.5
~ DAYS
~ DT
|

219. TIMEPR=MDRM/(WFS*ADMPPS)
~ DAYS
~ TIME PERCEIVED STILL REQUIRED
|

220. TIMERM=MAX(SCHCDT-Time,0)
~ DAYS
~ TIME REMAINING
|

221. TKDSCV=INTEG((TIME STEP*(1/TIME STEP)*((-1)*TKDSCV+
MAX((TKDSCV+TIME STEP*(RTDSTK-RTINCT)),0)))/TIME STEP,0)
~ TASKS
~ TASKS DISCOVERED
|

222. TM=Time
~ ~ |

223. TMDFED(0,1,2,3,4,5,6,7,8,9,10,50,36,26,17.5,10,4,1.75,1.2,1,1,1)
~ ~ |

224. TMDPSN=MDPNNT+MDPNTS+MDPNRW
~ MAN-DAYS
~ TOTAL MAN DAYS PERCEIVED STILL NEEDED
|

225. TMEGSP(-0.4,-0.2,0,0.2,0.4,0.6,0.8,1,0.9,0.94,1,1.05,1.14,1.24,1.36,1.5)
~ ~ |

226. TMEGWM(0,0.2,0.4,0.6,0.8,1,2,1.8,1.6,1.4,1.2,1)
~ ~ |

227. TMERED(0,10,20,30,40,50,60,70,80,90,100,1,1.1,1.2,1.325,1.45,1.6,2,2.5,3.25,4.35,6)
~ ~ |

228. TMODEX(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,1,0.9,0.8,0.7,0.6,0.5,0.4,0.3,0.2,0.1,0)
~ ~ |

229. TMPDEV(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,1,1,1,1,1,1,0.975,0.9,0.75,0.5,0)~ ~ |
230. TMPNPE=0.15
~ MAN-DAY/ERROR
~ TESTING MANPOWER NEEDED PER ERROR
|

231. TMPNPT=(TSTOVH*(DSIPTK/1000)+TMPNPE*(PERRDS+AERRDS))/MPDMCL
~ MAN-DAYS/TASK
~ TESTING MANPOWER NEEDED PER TASK
|

232. TMPREX(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,1,1,1,1,1,1,0.975,0.9,0.75,0.5,0)
~ ~ |

233. TMPRMR=0
~
~ TIME PARAMETER (= HIREDY+ASIMDY) DAYS
|

234. MPTPD(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,1,1.0125,1.0325,1.055,1.09,1.15,1.2,1.22,
1.245,1.25,1.25)
~ ~ |

235. TMSTOP=IF THEN ELSE(PJBAWK*M PULSE(Time,1,TIME STEP,
TIME STEP,40) >= 0.995,Time,MAXLEN)
~
~ FINAL TIME
|

236. TNERPK(0,0.2,0.4,0.6,0.8,1,25,23.86,21.59,15.9,13.6,12.5)
~ ~ |

237. TNOWDT(0,10,20,30,40,50,0,10,20,30,40,50)
~ ~ |

238. TNQAPE(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,0.4,0.4,0.39,0.375,0.35,0.3,
0.25,0.225,0.21,0.2,0.2)
~ ~ |

239. TNRWME(0,0.2,0.4,0.6,0.8,1,0.6,0.575,0.5,0.4,0.325,0.3)
~ ~ |

240. TNWRAD(0,5,10,15,20,25,30,2,3.5,5,6.5,8,9.5,10)
~ ~ |

241. TOTDMP=TOTWF*ADMPPS
~ MAN-DAYS/DAY
~ TOTAL DAILY MANPOWER
|
242. TOTMD=INITIAL(MDSWCH*(((2.4*EXP(1.05*LN(PJBDSI/1000)))*19)*(1-
UNDESM))+(1-MDSWCH)*TOTMD1)
~
~ TOTAL MAN DAYS
|

243. TOTMD1=GAME(TOTMD1INI)
~ MAN DAY
~ TOTAL MAN DAYS
|

244. TOTMD1INI=2360
~ MAN DAY
~ INITIAL ESTIMATED TOTAL MAN DAYS |

245. TOTWF=WFNEW+WFEXP
~ PEOPLE
~ TOTAL WF LEVEL
|

246. TPFMQA(0,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,0.15,0.15,0.15,0.15,0.15,0.15,0.15,
0.15,0.15,0.15,0)
~ ~ |

247. TPUTDD(0,20,40,60,80,100,0,0.4,2.5,5,10,100)
~ ~ |

248. TRIXHL(-0.5,-0.4,-0.3,-0.2,-0.1,7.45058e-009,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,
1,2.5,2.2,1.9,1.6,1.3,1.15,0.9,0.8,0.7,0.6,0.5,0.4,0.3,0.2,0,0)
~ ~ |

249. TRNFRT=MAX(0,-WFGAP/TRNSDY)
~ PEOPLE/DAY
~ TRANSFER RATE OF PEOPLE OUT OF PROJECT |

250. TRNSDY=10
~ DAYS
~ TIME DELAY TO TRANSFER PEOPLE OUT
|

251. TRPNHR=0.2
~ DIMENSIONLESS
~ NUMBER OF TRAINERS PER NEW EMPLOYEE
|

252. TSAEDS=40
~ DAYS
~ TIME TO SMOOTH ACTIVE ERROR DENSITY (AERRDS) |
253. TSHADT(0,5,0.5,5)
~ ~ |

254. TSKPRM=PJBSZ-CMTKDV
~ TASKS
~ NEW TASKS PERCEIVED REMAINING
|

255. TSKWK=INTEG((SDVRT-QART),0)
~ TASKS
~ TASKS WORKED
|

256. TSRATE=MIN(CUMTQA/TIME STEP,DMPTST/TMPNPT)
~ TASKS/DAY
~ TESTING RATE |

257. TSSZMD=INTEG((IRTSDT+(1/TIME STEP)*ARTJBM*IF THEN ELSE (FREFTS >= 0.9,1,0)),TSTMD)

~

~ PLANNED TESTING SIZE IN MAN-DAYS ... BEFORE WE START TESTING

|

258. TSTMD=INITIAL((1-DEVPRT)*TOTMD)

~

~ TESTING MAN DAYS

|

259. TSTOVH=1

~ MAN-DAYS/KDSI

~ TESTING EFFORT OVERHEAD

|

260. TSTPRM=PJBSZ-CUMTKT

~ TASKS

~ TASKS REMAINING TO BE TESTED

|

261. TSTSPD=50

~ DAYS

~ TIME TO SMOOTH TESTING PRODUCTIVITY

|

262. TWCWF1(0,0.3,0.6,0.9,1.2,1.5,1.8,2.1,2.4,2.7,3,0,0,0.1,0.4,0.85,1,1,1,1,1,1)

~ ~ |

263. TWCWF2(0.86,0.88,0.9,0.92,0.94,0.96,0.98,1,0,0.1,0.2,0.35,0.6,0.7,0.77,0.8)

~ ~ |

264. UDAVER=INTEG((AEGRT+AERGRT-AERRRT-DCRTAE),0)

~ ERRORS

~ UNDETECTED ACTIVE ERRORS

|

265. UDPVER=INTEG((PEGRT+AERRRT-DCRTPE),0)

~ ERRORS

~ UNDETECTED PASSIVE ERRORS |

266. UNDESM=0

~ FRACTION

~ MAN-DAYS UNDERESTIMATION FRACTION

|

267. UNDEST=0.33
~ FRACTION
~ TASKS UNDERESTIMATION FRACTION
|

268. UNDJTK=INTEG((-RTDSTK),RJBSZ-PJBSZ)
~ TASKS
~ UNDISCOVERED JOB TASKS
|

269. WCWF=MAX(WCWF1,WCWF2)
~ DIMENSIONLESS
~ WILLINGNESS TO CHANGE WORKFORCE LEVEL
|

270. WCWF1=TWCWF1(TIMERM/WCWFTP)
~ DIMENSIONLESS
~ WILLINGNESS TO CHANGE WORKFORCE (1)
|

271. WCWF2=TWCWF2(SCHCDT/MXTLCD)
~ DIMENSIONLESS
~ WILLINGNESS TO CHANGE WF (2) |
272. WCWFTP=IF THEN ELSE(TMPRMR = 0,HIREDY+ASIMDY,TMPRMR)
~
~ TIME PARAMETER DAYS
|

273. WFEXP=INTEG((ASIMRT-EXPTRR-QUITRT),WFSTRT)
~ PEOPLE
~ EXPERIENCED WORKFORCE INITIAL VALUE OF EXPERIENCED WORKFORCE LEVEL
|

274. WFGAP=WFS-TOTWF
~ PEOPLE
~ WORKFORCE GAP
|

275. WFINDC=(MDRM/(TIMERM+0.001))/ADMPPS
~ PEOPLE
~ INDICATED WORKFORCE |

276. WFNEED=MIN((WCWF*WFINDC+(1-WCWF)*TOTWF),WFINDC)
~ PEOPLE
~ WORKFORCE LEVEL NEEDED
|

277. WFNEW=INTEG((HIRERT-ASIMRT-NEWTRR),0)
~ PEOPLE
~ NEW WORKFORCE
|

278. WFS=MIN(CELTWF,WFS1/ADMPPS)
~ PEOPLE
~ WF SOUGHT
|

279. WFS1=GAME(WFSINI)
~ PEOPLE
~ TOTAL REQUESTED STAFFING LEVEL
|

280. WFS2=WFS1
~ PEOPLE
~ WORK FORCE SOUGHT
|

281. WFSINI=2
~ PEOPLE
~ INITIAL VALUE OF STAFFING LEVEL
|

282. WFSTRT=WFS1
~ MEN
~ TEAM SIZE AT BEGINNING OF DESIGN
|

283. WKRADY=NWRADY*EWKRTS
~ DAYS
~ WORK RATE ADJUSTMENT DELAY
|

284. WKRTS=(1+PBWKRS)*NFMDPJ
~ DIMENSIONLESS
~ WORK RATE SOUGHT
|

285. WRADJR=(WKRTS-AFMDPJ)/WKRADY
~ 1/DAY
~ WORK RATE ADJUSTMENT RATE
|

286. WTOVWK=IF THEN ELSE(Time >= BRKDTM+RLXTMC,1,0)
~ ZERO OR ONE
~ WILLINGNESS TO OVERWORK
|

287. WTPJDP=MPWDEV*MPWREX
~ DIMENSIONLESS
~ WEIGHT TO PROJECTED DEVELOPMENT PRODUCTIVITY
|

LIST OF REFERENCES

Abdel-Hamid, Tarek K., "Adapting, Correcting, and Perfecting Software Estimates: A Maintenance Metaphor," IEEE Computer Journal, March 1993.

________. "Investigating the Cost/Schedule Trade-Off in Software Development," IEEE Software, January 1990.

________. "The Dynamics of Software Project Staffing: A System Dynamics Based Simulation Approach," IEEE Transactions on Software Engineering, VOL. 15, No. 2, p. 109-119, February 1989.

Abdel-Hamid, Tarek K., and Stuart E. Madnick, Software Project Dynamics, An Integrated Approach, Prentice Hall Inc., 1991.

Austin, Larry M., and Parviz Ghandforoush, Management Science for Decision Makers, West Publishing Company, 1993.

Davis, Richard D., Jr., Design and Development of a User Interface and User Manual for the Software Management Flight Simulator, Master's Thesis, Naval Postgraduate School, Monterey, California, September 1995.

Ehrhart, Lee S., May 1990, New Approaches to Human-Computer Interaction Research and Design for Decision Aiding Systems, [CD-Rom] IEEE Publications Ondisk, File: TH0333-5/90/0000/0847. Available: ProQuest Library, 1995.

Investigative Report of Senator William S. Cohen, Ranking Minority Member, Subcommittee on Oversight of Government Management, Senate Governmental Affairs Committee, Computer Chaos: Billions Wasted Buying Federal Computer Systems, Washington, D.C., GPO, October 12, 1994.

Jensen, Robert E., "The Technology of the Future is Already Here," Academe, 1993.

Jones, Capers, Assessment and Control of Software Risks, Yourdon Press Computing Series, Prentice Hall, Inc., 1994.

Larkin, Jill H. and Ruth W. Chabay, ed. 1992, Computer Assisted Instruction and Intelligent Tutoring Systems - Shared Goals and Complementary Approaches. Chapter 5, A Practical Guide for the Creation of Educational Software, by Ruth W. Chabay and Bruce A.Sherwood, Hillsdale, Lawrence Erlbaum Associates.

Neimeier, Henry, "A System Dynamics Model of the Standard Development Process," IEEE, 1990.

Pressman, Roger S., A Manager's Guide to Software Engineering, McGraw Hill, Inc., 1993.

Reifer, Donald J., ed., Software Management, 1993, California: IEEE Computer Society Press.

Reifer, Donald J., ed., 1993. Software Management. The Mythical Man-Month, by Frederick P. Brooks, Jr. California: IEEE Computer Society Press.

Roberts, Edward B., "System Dynamics - An Introduction," In Managerial Applications of System Dynamics, ed. Edward B. Roberts, Cambridge, MA, The MIT Press, 1981.

Senge, Peter M., The Fifth Discipline, New York, New York, Currency Doubleday, 1994.

________. "System Thinking and Organizational Learning: Acting Locally and Thinking Globally in the Organization of the Future," Forthcoming in Transforming Organizations, ed.s T. Kochan and M. Useem, Oxford, Oxford University Press, 1991.

Shneidederman, Ben, Designing the User Interface, Strategies for Effective Human-Computer Interaction, Addison-Wesley Publishing Company, 1992.

Sprague, Ralph H., Jr., and Barbara C. McNurlin, Information Systems Management in Practice, Englewood Cliffs, N.J., Prentice Hall, 1993.

U.S. General Accounting Office, Report to the Chairman, Committee on Government Affairs, U.S. Senate, Software Tools, Defense is not Ready to Implement I-Case Departmentwide, GAO/IMTEC-93-27, Washington D.C., GPO, June 1993.

Ventana Systems, Inc., Vensim Reference Manual, Version 1.61, 1994.

________. Vensim User's Guide, Version 1.61, 1994.

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center..2
   8725 John J. Kingman Rd., STE 0944
   Ft. Belvoir, Virginia 22060-6218

2. Library, Code 52..2
   Naval Postgraduate School
   Monterey, California 93943-5101

3. Dr. Tarek Abdel-Hamid, Code SM/AH...5
   Department of Systems Management
   Naval Postgraduate School
   Monterey, California 93943

4. Dr. Balasubramaniam Ramesh, Code SM/RA...2
   Department of Systems Management
   Naval Postgraduate School
   Monterey, California 93943

5. Maj Luis Hernandez..1
   P.O. Box 1010
   Ft. Meade, Maryland 20755-3010